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SHELTER FIRE VULNERABILITY - SURVEY AND ANALYSIS OF REPRESENTATIVE BUILDINGS

Final Report

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D.C., 20310

Contract No. OCD-OS-62-210
OCD Work Unit 2522A

IIT RESEARCH INSTITUTE

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Technology Center
Chicago, Illinois 60616

SUMMARY

OF

RESEARCH REPORT

# SHELTER FIRE VULNERABILITY - SURVEY AND ANALYSIS OF REPRESENTATIVE BUILDINGS

IITRI Project No. N6005
Contract No. OCD-OS-62-210
OCD Work Unit 2522A

by

R. B. Varley and G. L. Maatman

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D.C., 20310

March 17, 1965

OCD REVIEW NOTICE

This report provides a detailed fire protection engineering analysis of the fire vulnerability of a selected national sample of stocked fallout shelters. While the findings are not necessarily representative of magnitude, they are representative of the nature of the fire vulnerability of fallout shelters.

Acceptability criteria for fire-safe fallout shelters; upgrading measures, including fire extinguisher needs; and fallout shelter building code criteria are proposed.

This report has been reviewed in the Office of Civil Defense and approved for publication.

Qualified requestors may obtain copies of this report from the Defense Documentation Center. The DDC will make copies of the report available to the Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Virginia 22151 for sale to the general public.

## OBJECTIVE

The objective of this study is to analyze the potential fire vulnerability of fallout shelters exposed to fires emanating from various sources, including a nuclear burst.

## SCOPE

The study consists of an evaluation of the vulnerability of fallout shelters to fires from accidental sources as well as from the direct nuclear weapon effects. It also includes the development of operational guidance for the selection and upgrading of shelter buildings, the establishment of recommended fallout shelter provisions for public building codes, and the identification of worthwhile areas for future study and development.

## PROBLEM DISCUSSION

Shelter buildings have been chosen throughout the country to meet the requirements for protection against fallout. Typically, these shelters are found in public or commercial buildings having construction of sufficiently high density. These buildings must be at sufficient distance from the burst that blast effects will not seriously damage the shelter. At such distances from the burst, however, ignition of kinding materials by the thermal pulse is possible. Under fallout conditions, no outside aid from professional fire fighters can be anticipated, nor can shelter occupants expect to be able to flee a burning structure.

## APPROACH

The primary consideration in judging the degree of fire vulnerability of a shelter building, is to measure the fire hazards faced by its occupants under attack conditions. These hazards can be due to the direct effects of fire, such as, heat, toxic gases, and oxygen depletion, or due to nuclear radiation exposure of occupants evacuating a burning structure or fighting fire in unshielded areas. The degree of fire hazard depends on two factors. The first is the number and location of fires initiated within and in the proximity of the shelter building. The second is the type of construction, occupancy, and internal layout of the shelter building itself, as well as of adjacent buildings. Considering that one cannot predict the location of initial fires, the assumption is made here that any combustibles within the shelter building or within adjacent buildings are subject to ignition. Furthermore, the shelter building is assumed to be materially unchanged by the blast from the nuclear burst. Under these assumptions, the vulnerability of shelter buildings has been determined for various fire conditions, excluding mass fires.

The possible hazard of direct fire spread within the shelter building has been determined through comparison of active burning times with the rated duration of fire resistance of the building compo[illegible] This comparison was made for an assumed ignition of [illegible] floor by considering in steps, increasing areas of fire involvement until either fire resistance exceeded fire duration or the entire building was involved. The fire durations were determined by considering the weight of combustibles (fire load) and relating it to the peak fire burning rate. Burning rate was taken to be that for either ventilation controlled or fuel surface controlled burning, whichever was less.

Four structural features were selected as having a significant bearing on minimizing the spread of smoke and fire gases. These are: 1) sufficient interior barriers to limit fire spread to the average partitioned area of a shelter building floor, 2) sufficiently large ventilation that the rate of burning approached fuel surface control, 3) absence of minor openings between floors, and 4) doors at each level in all stair and elevator shafts.

The potential for ignition from burning adjacent buildings was determined from the level of radiant heat transmitted to the shelter building. This level was evaluated in terms of the minimum number of adjacent burning buildings which would be required to ignite the shelter building.

A determination was made for each shelter building of whether or not suppression of fire would be possible if sufficient manpower were available equipped only with portable extinguishers.

It was assumed that only incipient fires could be extinguished using this equipment, thus effective fire fighting depended on discovery of all fires in the incipient state

Because of this, fires involving rapid build-up, or concealed or inaccessible spaces, were not considered to be extinguishable. Where portable extinguishers were judged to be inadequate, the feasibility of using existing fixed extinguishment systems was studied.

FINDINGS

A. Characteristics of Fallout Shelter Building

Based on information gathered from 102 buildings selected as representative of those available in the 24 cities initially having stocked fallout shelter buildings, the following conditions are considered characteristic:

1. Fire resistive construction will be prevalent, although some unprotected steel and masonry wood joist structures may be found. Principal floor openings will generally be enclosed, but enclosures may be lacking in some localities.

2. The normal occupancies of most shelter buildings will consist of those types generally found in commercial and public buildings.

3. Significant numbers of portable extinguishers are to be found in a majority of buildings. Standpipe and hose installations are less often available. Automatic sprinkler systems are found for the most part only in particular types of occupancies.

4. Generally, fewer shelter areas will be found aboveground than below ground. However, the majority of the shelter population will be in above-ground shelters.

B. Fire Vulnerability of Shelter Building

Analysis of survey shelter buildings revealed varying degrees of vulnerability in one or more of the following five fire-safety attributes.

1. Fire would be contained within the floor of origin in fire resistive structures in several occupancy groupings. Schools, churches, offices, banks, residentials, and telephone exchanges would resist fire spread either when a good degree of subdivision exists within each floor, or when all floor to floor openings are protected. Manufacturing buildings with low combustible loading (1-3 pounds per square foot), and those with moderate loading having protected floor openings would also resist the spread of fire.

2. Well-subdivided structures capable of preventing fire spread away from the floor of origin would require only minimum efforts by occupants to prevent smoke and toxic gases from reaching dangerous levels. When such structural characteristics are lacking, special equipment and materials must be employed by occupants to effectively minimize the spread of smoke and toxic gases.

3. Approximately two-thirds of the surveyed buildings in "downtown" areas and one-third of those in exclusively residential areas were exposed to ignition from nearby burning structures. Approximately one-half of all buildings

exposed to ignition from adjacent buildings could be exposed on more than one side.

4. With few exceptions, fire suppression by shelter occupants could be effectively accomplished with sufficient portable extinguishers. Properly supplied standpipe and hose or automatic sprinkler systems will control fire in those exceptional occupancies where rapid fire buildup is characteristic, or where access to combustibles is prevented by considerable bulk storage or concealed combustible building construction.

5. The contribution of shelter stock to the peacetime fire severity of shelter buildings is significant only when storage of the combustible portion of these supplies exceeds 100 square feet of floor area and when the normal-occupancy fire loading is relatively light. Such conditions occur when stocks for large shelter areas located on several above-ground floors are stored in one location. In most cases, combustible shelter supplies will occupy less than 100 square feet when the shelter area and its supplies are located on the same floor.

## OPERATIONAL GUIDANCE

### A. Levels of Fire Vulnerability

The criteria for the selection of new fallout shelter buildings and the upgrading of existing facilities should include the relative degree of fire vulnerability, as well as the ability to protect against fallouts. It was shown in previous analyses that an ignition in the shelter building could be satisfactorily controlled through containment of fire in a portion of the building by means of structural fire resistance or through rapid discovery and extinguishment by shelter occupants. Preference should be given to buildings with fire containment structural characteristics as the safety of fallout shelters in these structures is less dependent upon the activity of occupants. However, reliance on fire extinguishment will give favorable results when occupants are adequately organized, equipped, and trained for fire fighting and where these activities are not curtailed by nuclear radiation. The order of preference is given below using shelter building categories developed in the previous analyses.

1a) Fire Limiting - No combustibles outside shelter areas.

1b) Fire Limiting - Fire gases controllable without special means.

1c) Fire Limiting - Fire gases controlled with special means.

2 ) Suppression Dependent

3a) Untenable - Fire not controllable with portable extinguishers.

3b) Untenable - Problem other than extinguishment.

1. Fire Limiting

Fire limiting buildings are those in which fully developed fires originating outside shelter floors will not progress to these floors. The analysis indicates that shelter buildings resisting the spread of direct fires would mainly include those used as schools, churches, offices, banks, residential types, telephone exchanges, and manufacturers with low combustible contents loading. A method for selection of fire limiting buildings is presented.

As the resistance to direct spread of fire does not preclude possible spread of smoke and toxic gases, this characteristic of Fire Limiting buildings must be determined separately.

2. Suppression Dependent

This intermediate fire vulnerability level denotes those instances where fire spread cannot be adequately resisted by the building members, but it is possible to extinguish all incipient fires using portable extinguishers. This level includes all buildings not specifically falling in either of the other two categories.

3. Untenable

This fire vulnerability level consists of buildings where extinguishment of fire using portable equipment is considered unfeasible due to excessively rapid fire buildup, or concealed or inaccessible combustibles. Identification of buildings having these characteristics can be made from the following illustrative situations.

a) Buildings where explosive vapors or dusts may be present such as automobile garages and certain types of industrial occupancies.

b) Buildings with significant accumulations of wood scraps, paper, and textiles.

c) Buildings having contents storage such that combustible stock piles are high and/or with the absence of adequate aisle space between adjacent piles.

d) All buildings of masonry and wood joist constructions, as in these structures concealed and inaccessible combustible spaces predominate.

B. Acceptability Criteria

The following factors should be considered in evaluating the potential acceptability of a building for fallout shelter use:

1) Buildings of all fire vulnerability levels must be free from severe exposure to ignition from nearby structures. As a guide to such determinations, the method of calculating building separations by Margaret Law can be used.

2) Buildings of all vulnerability levels should be protected from ignition by the thermal pulse of the nuclear weapon in so far as possible.

3) Buildings of all vulnerability levels should be provided with adequate portable fire extinguishing equipment.

4) Special facilities should be provided for controlling fire gases in Fire Limiting buildings where this need has been determined.

5) Access within Suppression Dependent buildings should not have to be limited (by nuclear radiation) to intervals so

short that fire discovery and extinguishment efforts will be curtailed. A minimum shielding value, possibly a protection factor of at least 100, should be selected as a criteria.

6) Untenable shelter buildings should be provided with adequate and properly supplied, fixed extinguishment systems.

7) Untenable buildings where toxic and flammable vapors are found, principally automobile parking garages, should be supplied with reliably-powered mechanical ventilation equipment.

C. Upgrading Shelter Buildings

1. Reducing Spread of Smoke and Toxic Gases

The extent to which smoke and toxic gases can spread through a building, as has previously been indicated, is dependent in part on its interior configuration, the degree to which it is subdivided by partitions and doors, and the extent to which its various floor openings are protected. Therefore, it is possible to reduce this hazard through structural alterations, especially in those portions adjacent to shelter areas.

In any case, shelter areas themselves must be sealed off from the remainder of the building in a manner sufficient to exclude smoke and toxic gases. This will necessitate the grouting of any wall or floor openings around ducts or piping which pass through the shelter area and the sealing of any cracks or openings around doors leading into the shelter area after it has been occupied. In addition, provisions should be made to seal all supply or exhaust openings in air ducts within the shelter area if the need arises.

2. Reducing Fire Spread

It is not expected that all shelter buildings classed as Suppression Dependent can reasonably be upgraded to a better classification because of operational space and traffic needs inherent in certain types of occupancies.

Improvement of interior barriers to fire in buildings selected as shelters would most often take the form of strengthening doorways.

A structure having deficient ventilation may be improved by providing automatic fire vents at the top of stairwell and elevator shafts.

To aid in making judgments as to necessary minimum improvements, a numerical system for the assessment of shelter fire spread is proposed here. This is an empirical method developed for identifying buildings which should class as Fire Limiting.

3. Protection against External Fire Exposure

Means for shielding exterior windows against the penetration of radiant heat energy should be provided both for protection from nuclear weapons and nearby burning structures. Such protection is necessary for all shelter buildings, but is especially important in Suppression Dependent buildings where numerous ignitions would become impossible to extinguish. The protection from nearby buildings can be limited to walls facing such buildings, while protection from the thermal pulse will be necessary for all windows from which the sky can readily be observed. The window shielding may take the form of either a pre-installed device such as a reflective screen or as a coating applied in the emergency or a combination of both. A more substantial means, such as outside sprinkler protection, may be needed where exposure from nearby buildings is severe.

4. Portable Fire Extinguishers

Current NFPA standards recommend one 2-1/2 gallon water type extinguisher (or equivalent) for each 2500 square feet floor area in normal hazard occupancies, for fires in ordinary combustible materials such as wood, cloth, paper, etc. In light hazard occupancies, i.e., office buildings, schools, etc., the allowable floor area is doubled. The five-gallon stirrup pump extinguisher, considered equivalent to two of the above extinguishers, has been found to be the most satisfactory type. The requirements for portable extinguishers recommended for meeting the needs for "extinguishability" as set forth by Salzberg et al are as follows: Each occupied shelter area should be provided with a minimum of four 5-gallon stirrup pump extinguishers plus one additional for each 1250 square feet of shelter area in excess of 5000 square feet. Nonshelter areas of Suppression Dependent buildings should be provided with one stirrup pump extinguisher for each 2500 square feet of floor area and nonshelter areas of Fire Limiting buildings should be provided with one for each 5000 square feet. In nonshelter areas, existing 2 1/2 gallon Class A extinguishers installed for normal use may be accepted in lieu of stirrup pumps on a two for one basis. The above requirements may be halved in "light hazard" occupancies. The survey indicated that, in most buildings, special extinguishers are already installed where needed for flammable liquid or electrical fire hazards (Class B or C Fires).

5. Fixed Extinguishment Systems

Standpipe and hose and automatic sprinkler systems with adequate and reliable water supplies can be installed in shelter buildings which would otherwise be classed as untenable due to large contents bulk or rapid fire build-up. Sprinkler systems also have the advantage of functioning in areas where access by personnel is limited by fallout.

Present NFPA standards for standpipe and hose systems for occupants use provide that not over 75 foot lengths of 1-1/2" hose be used at each hose station and that they be spotted so as to reach to within 20 feet of every point in the building.

Where it is determined that a public water system would not provide a reliable fire protection supply for sprinkler or standpipe and hose systems under attack conditions, a private self-contained supply in the form of a pressure tank or some equivalent means should be provided within the shelter building.

FALLOUT SHELTER BUILDING CODE CRITERIA

Building code criteria have been developed for fallout shelter buildings in a manner intended to limit fire vulnerability such that occupants can safely remain within protected portions without outside assistance from professional fire-fighting personnel.

Differentiation is made between existing (pre-ordinance) and new buildings to the extent necessary to avoid discouraging owners of existing buildings from offering the use of their structures for shelter purposes due to prohibitive alteration costs. Recommended building code provisions are given in the following table.

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Resistance to spread of smoke and toxic gases | Physically separate each shelter area from remainder of building with walls and tight fitting doors of required fire resistance | (1) Physically separate each shelter area from remainder of building with walls and tight fitting doors of required resistance<br>(2) Provide maximum interior compartmentation on each floor level throughout the building with emphasis on floor levels housing shelters<br>(3) Air duct systems should be arranged so as to minimize the possible transfer of smoke and toxic gases into any shelter area. |
| Ingress facilities (see Note 4) | Provide sufficient ingress facilities from the outside to each shelter area, on the basis of 150 persons per 22" unit of stairway width and 200 persons per 22" unit of door width, so as to be able to adequately handle the entire rated shelter capacity | Provide sufficient ingress facilities from the outside to each shelter area, on the basis of 150 persons per 22" unit of stairway width and 200 persons per 22" unit of door width, so as to be able to adequately handle the entire rated shelter capacity. |

TABLE V (cont)

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
| --- | --- | --- |
| Portable fire extinguishers | Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 1250 square feet of shelter area with a minimum of 4 extinguishers per shelter<br><br>Non-Shelter Areas - provide one unit of extinguishing capacity for each 1250 square feet of floor area. Where the existing complement of extinguishers is inadequate, supplement these specifically with the installation of 5-gallon stirrup pump type extinguishers on the basis of 5000 square feet per extinguisher | Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 1250 square feet of shelter area with a minimum of 4 extinguishers per shelter<br><br>Non-Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 5000 square feet of floor area |

## RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Combustible contents | Highly flammable contents such as combustible fibers (cotton, jute, sisal, etc....), flammable liquids, hazardous chemicals, dusts, etc.... shall not be permitted within the building except in nonshelter areas and then only if separated from all other portions of the building by walls, floors and doors having adequate fire resistance and if stored in accordance with nationally recognized standards of safe practice. | <u>Shelter Areas</u> - combustible contents should be restricted to that necessary in connection with operating the shelter in an emergency<br><br><u>Non-Shelter Areas</u> - highly flammable contents such as combustible fibers (cotton, jute, sisal, etc....), flammable liquids, hazardous chemicals, dusts, etc... should not be permitted within the building. In addition, the maximum permissable combustible fire load for any floor level should not exceed an average of 15 pounds per square foot of floor area. |

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Fire resistance of walls, floors, roof and their supports | Minimum 2 hours (see Note 1) | Minimum 2 hours except 3 hours for primary floor and roof supports (see Note 2) |
| Protection of vertical openings | 1 hour | 2 hours (see Note 2) |
| Interior finish (see Note 3) | Flame spread of not greater than 25 in shelter areas; 200 in other parts of building | Flame spread of not greater than 25 in shelter areas; 75 in other parts of building |
| Exterior wall openings | Provide some means of shielding to protect from the thermal pulse of a nuclear weapon | (1) Provide some means of shielding to protect from the thermal pulse of a nuclear weapon.<br>(2) Provide approved wired glass in metal frames in any opening exposed by an adjacent building. |

NOTES:

1. An existing building having structural components of less than 2 hours fire resistance may be accepted if, in the opinion of the enforcing authority, its occupancy, interior configuration, etc., is such as to enable it to be classed as Suppression Dependent.
2. Where the anticipated combustible fire load of a building is less than 10 $lbs/ft^2$, the required fire resistance for primary floor and roof supports and vertical opening protective assemblies may be reduced to 2 hours and 1 hour respectively.
3. Flame spread ratings are based on the A.S.T.M. E-84 Tunnel Test method.
4. Capacity of ingress facilities is based upon half of the egress facilities normally required for an assembly type occupancy by the N.F.P.A. Building Exits Code and ideally permits the last person to reach the shelter area 3-1/2 minutes after the first person passes through a shelter area doorway. Although facilities would be considered inadequate from a peacetime egress standpoint, it must be recognized that "emergency" egress under post-attack conditions would probably be pre-planned and carefully controlled. In addition, the application of normal exit capacity requirements to most shelter ingress situations would produce prohibitive requirements in all except shelter buildings having a peacetime assembly occupancy.

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# SHELTER FIRE VULNERABILITY - SURVEY AND ANALYSIS OF REPRESENTATIVE BUILDINGS

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This report provides a detailed fire protection engineering analysis of the fire vulnerability of a selected national sample of stocked fallout shelters. While the findings are not necessarily representative of magnitude, they are representative of the nature of the fire vulnerability of fallout shelters.

Acceptability criteria for fire-safe fallout shelters; upgrading measures, including fire extinguisher needs; and fallout shelter building code criteria are proposed.

This report has been reviewed in the Office of Civil Defense and approved for publication.

## ABSTRACT

The vulnerability of fallout shelters to fires from accidental sources as well as from direct nuclear weapon effects are evaluated. This was accomplished by survey and analysis of 102 stocked shelter buildings in eleven cities chosen to give reasonable diversity in size, industrial and commercial emphasis, and geographic location. Operational guidance developed for the selection and upgrading of shelter buildings and recommended fallout shelter provisions for public building codes are established for both existing structures and new construction. Areas for future study and development are identified.

## FOREWORD

"Shelter Fire Vulnerability - Survey and Analysis of Representative Buildings" is one of three final reports presented on this project sponsored by the Office of Civil Defense under Contract No. OCD-OS-62-210. This fulfills in part, the project objective of analyzing the fire defenses of urban areas in general, and of shelter buildings in particular, exposed to the thermal pulse and fallout from a nuclear burst.

IIT Research Institute personnel contributing to this project include: C. Caccavari, W. G. Labes, G. L. Maatman, F. Salzberg, R. B. Varley and T. E. Waterman. Consultants to this portion of the project were J. W. Clear, R. S. Moulton, (Consulting Fire Protection Engineer), and B. R. Townsend (International Association of Fire Chiefs).

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# I. INTRODUCTION

## A. Scope of Work

The scope of work of the contract as amended was: "The contractor shall review the conditions under which fire fighting must occur, evaluate the utility of organized and continued fire suppression within the first half hour after detonation and explore what other suppression techniques might be useful under the circumstances. The contractor's specific investigation shall include: (a) evaluation of the present state of knowledge regarding the problem of mass fires produced by thermonuclear attack in which extinguishment of ignitions of small fires immediately following attack can be an effective means of preventing the growth of mass fires with the possibility of arrival of fallout as soon as 30 minutes after detonation, making such efforts infeasible; (b) identification of areas where additional knowledge of natural laws is needed; (c) study of effects of radiological fallout hazard on conventional or modified fire fighting techniques; (d) determination of additional research and experimental procedures for attaining the objectives listed above, "and" the additional work and services shall include, but are not limited to, the following areas:

(1) fire prevention, including the reduction of fire vulnerability,

(2) self-help fire extinguishment, and

(3) organized operations capabilities for large-scale fire fighting rescue and related areas."

The results of the investigation are presented in three reports. The present report treats the subject of fire vulnerability of fallout shelters in fulfillment of Items 1 and 2 of the "additional work and services," in the scope of work. The specific objectives of the report are: 1) evaluation of the vulnerability of fallout shelters to fires emanating from various sources, including a nuclear burst, and 2) development of fire protection criteria for the selection, modification, and construction of fallout-shelter facilities.

The second report on the subject of fires in fallout shelters deals with the activity required of shelter occupants. It is entitled, "Shelter Fire Vulnerability-Specific Fire Limiting Activities of Occupants."

The objectives of the scope of work, as applied to the over-all fire defenses of urban areas, are dealt with in a third report entitled, "An Approach to Trans-Attack Fire Suppression in Urban Areas."

B. Approach

The primary considerations in judging the fire vulnerability of a shelter building are the fire hazards faced by its occupants under attack conditions. These hazards can include the direct effects of fire, such as, heat, toxic gases, and oxygen depletion, as well as exposure to nuclear radiation while fighting fire in unshielded areas or after fleeing a burning structure. The degree of fire hazard depends on two factors. The first is the number and location of fires initiated within and in the proximity of the shelter building. The second is physical layout, including the type of construction, occupancy and internal configuration of the shelter building itself and of adjacent buildings.

Since the location of initial fires cannot be predicted, the assumption is made here that any combustibles within the shelter building or adjacent buildings are subject to ignition. Furthermore, the shelter building is assumed to be materially unchanged by the blast of the nuclear burst. Under these assumptions, the vulnerability of shelter buildings has been examined for various fire conditions, excluding mass fires. The investigation has included the hazard of direct spread of fire to shelter areas from ignitions within the shelter building or from adjacent burning buildings, the spread of smoke and toxic gases, the feasibility of fire suppression by shelter occupants using portable extinguishers, and the significance of fixed extinguishment systems. Further, the influence of shelter provisions on the peacetime fire hazard is explored

In most cases, the analyses were performed using natural laws governing the behavior and effects of free burning fires. In some instances, where such knowledge was not available, the conclusions were reached using engineering judgment. The necessary data for the study was obtained by on-site surveys of existing fallout shelters.

## II. SHELTER BUILDING SURVEY

### A. Objectives of Survey

The information collected in the survey was to be used for performing specific analyses of fire hazards, as well as to supply the usual criteria needed by the fire protection engineer. The analyses of fire hazards, which include interior fire spread, fire spread from nearby buildings, and spread of smoke and toxic gases, are discussed in the next chapter.

For the consistent and accurate gathering of information, a set of four forms was drawn up which outlined the type and emphasis of data desired. Detailed information was noted about those areas and floors which contained shelters; and the remainder of the building surveyed in more general terms. Neighboring structures and other pertinent external features were also considered. The forms used are shown on pages A-2 to A-12 of Appendix A, including a sample of the information obtained for each building.

Two forms were set up for the shelter floors themselves, Form B for the structural items, and Form C for the contents and building equipment. Items considered in Form B were: area, shelter capacity, ceiling height, and materials used for walls, ceilings and floors. Also noted were details of all openings in the shelter, including a tabulation of doorways, giving their use, width, height, opening direction, and construction. Information concerning fire-protection equipment, both portable extinguishers and fixed systems, was also included.

The contents of the building, including service equipment and process equipment, as well as utilities on floors containing the shelter, were listed in Form C. Locations of these items were noted relative to areas designated as shelter space. Also, quantities of shelter supplies and possible future shelter support equipment were recorded.

The over-all description of the building was detailed on Form A in terms of two categories: construction and occupancy. Age, area, height, construction, exterior wall openings, nature of floor openings, and building service equipment were shown. Occupancy was noted indicating special uses, such as merchandise or material storage, and manufacturing equipment.

Form D, entitled "Environmental Data", described all structures having any portion located within one hundred feet of the shelter building. Items considered were: construction, occupancy, height, ground-floor area, window openings, and distance from shelter building. Other pertinent features were noted, such as tracks, tunnels and bridges, and proximity of gas mains, transformers, power lines, and sewers.

The data collected were supplemented by drawings which included: 1) a floor plan of the ground floor of the shelter building, 2) floor plans of all shelter floors of the building, and 3) a map showing the locations of surrounding buildings. Photographic coverage was used to the greatest possible extent. In addition, summaries were prepared to relate the general impressions obtained.

B. <u>The Sampling</u>

From its inception, the survey was concerned only with stocked shelters. This was done to check the possible effect of shelter supplies on the fire situation, and also to assure that the buildings had been completely processed by the administrating authorities and found acceptable. The initial selection was made from the list of 940 stocked structures within twenty-four "Accelerated Provisioning Cities," shown in Table 1.

Nine cities initially selected from the list were: Buffalo, New York; El Paso, Texas; Green Bay, Wisconsin; Los Angeles, California; Newark, New Jersey; Seattle, Washington; and Washington, D. C. These were chosen as giving reasonable diversity in size, industrial and commercial emphasis, and geographic location. Chicago and Evanston, Illinois were used in later surveys when stocked shelters became available there. Within each city, about 15 shelter buildings were selected, with the intent to represent various occupancies from among significant types found. In total, 102 shelter buildings were chosen which were considered to give an adequate sampling.

C. <u>Information Obtained</u>

1. Variations in Shelter-Building Construction

a. Structural types

Of the 102 buildings surveyed, eighty-six were found to be entirely of fire-resistive construction. Six other fire-resistive structures have sections of wood joist construction

TABLE 1

ACCELERATED PROVISIONING CITIES

| Locations | Shelter Buildings | Stocked Spaces |
|---|---|---|
| Albuquerque, New Mexico | 26 | 7,546 |
| Baltimore, Maryland | 24 | 15,087 |
| Buffalo, New York | 65 | 15,149 |
| Camden, New Jersey | 39 | 25,015 |
| Denver, Colorado | 31 | 34,554 |
| Des Moines, Iowa | 68 | 31,790 |
| East St. Louis, Illinois | 19 | 7,565 |
| El Paso, Texas | 40 | 8,755 |
| Green Bay, Wisconsin | 8 | 5,737 |
| Jacksonville, Florida | 20 | 50,534 |
| Little Rock, Arkansas | 26 | 21,488 |
| Long Beach, California | 25 | 10,461 |
| Los Angeles, California | 47 | 23,576 |
| Louisville, Kentucky | 63 | 50,000 |
| Newark, New Jersey | 72 | 3,840 |
| Oklahoma City, Oklahoma | 57 | 70,142 |
| Phoenix, Arizona | 17 | 21,635 |
| Sacramento, California | 6 | 20,000 |
| Salt Lake City, Utah | 2 | 604 |
| St. Louis, Missouri | 54 | 32,352 |
| St. Paul, Minnesota | 72 | 24,449 |
| Seattle, Washington | 45 | 34,374 |
| Washington, D. C. | 57 | 69,027 |
| Wichita, Kansas | 34 | 11,830 |
| TOTAL ---------------------- | 940 ------- | 595,510 |

(masonry walls with combustible floor and roof structrual members). Five buildings have unprotected steel members (columns and beams) supporting concrete floors. Five buildings are entirely of wood-joist construction.

Of the fire resistive structures, 61 are constructed with reinforced-concrete floors and supports, 21 have masonry bearing walls supporting reinforced-concrete floors, and 10 have concrete floors with protected structural steel frames.

In the 92 buildings without wood structural members, 48 have wood doors and trim. Eleven have wood floor surfacing and a great number were found with vinyl, asphalt tile, or linoleum surfacing. However, only a few were found to have combustible acoustic-tile ceilings or wood wall paneling.

b. Subdivision of buildings

Thirty-four structures, mostly schools, offices, and residential types, were found to have a significant degree of subdivision by partitions on each floor. However, the survey revealed that the floor subdivisions do not always coincide with the shelter-area boundary.

Major floor openings in subdivisions are protected with doors or enclosures in 73 buildings. Of these, 24 were found to have all elevator and stair shafts protected with masonry enclosures having doors at each level. Unprotected floor openings between at least two floors exists in 29 buildings. Minor floor openings, ducts, pipe chases, and bussways were observed in 89 buildings. Fire dampers in duct systems are often lacking, particularly on high velocity air conditioning systems.

2. Peacetime Occupancies of Shelter Buildings

The occupancies of the 102 shelter buildings surveyed are as follows. Fourteen are school and church types (essentially classroom types with open auditoriums) including one downtown business school, two college classroom buildings, five high and junior high school buildings, four grade schools, and two churches.

Twenty-three are office type buildings including five banks, five government office buildings, and thirteen general office structures. Four of the general office buildings have mercantile occupancies on the first floor. One state government office was constructed as a blast-resistant shelter.

Fifteen are residential type buildings including two homes for the aged, two hospitals, one orphanage, one hotel, one YMCA, and eight apartment houses.

Nine are manufacturing buildings including five occupied for light manufacturing, one clothing factory, one cannery, and two cement plants.

Eight warehouses surveyed included two used for paper and wood products, two for hardware and heavy appliances, one for pharmaceuticals, one for photographic supplies, and two for general storage purposes.

Ten mercantile establishments surveyed included one retail store, one bookstore, one musical-instrument store, and seven department stores.

Five publishing firms surveyed included two newspapers, one heavy printing, and two light printing establishments.

Six are theater or arena type structures including three motion-picture theaters, a college drama building, a television studio, and a high school gymnasium.

Five garages surveyed included three automobile-parking structures, a bus garage, and an automobile sales and service organization.

The remaining seven of the surveyed buildings included two post offices, two libraries, and three telephone or fire alarm exchanges.

3. Extinguishment Facilities Present

Significant fire extinguishment means for use by occupants were found in 84 buildings. Of these, 55 have portable extinguishers only, 5 have standpipe and hose systems only, and 24 have both means provided. Sixteen buildings, principally those used as garages, warehouses, publishing firms, and retail stores, are protected by complete automatic sprinkler installations. Two of these have water supplies auxiliary to the city system. Partial sprinkler protection exists in 26 shelter buildings, principally in basement areas.

4. Location of Shelters within Buildings

Of the 102 buildings surveyed, 59 have shelter spaces in basements only, 3 have spaces above the ground only, and 40 have spaces both above ground and in basements. The total number of occupants provided for in these shelters is 166,406. Of these, 90,695 would be above ground and 75,711 in basements.

5. Location of Shelter Buildings within City

The surveys indicated that the shelters tend to be concentrated around the principal business districts. Shelters in department stores, offices, banks, garages, etc., were found centered in this district. Shelter buildings containing manufacturers, publishers, warehouses, and apartment houses appeared toward the fringes of the business district. Only shelters in schools, hospitals and churches were found located in all areas throughout the city.

## III. DETERMINATION OF FIRE VULNERABILITY

### A. Methods of Analysis

1. Interior Fire Spread

Fire spread within a structure is governed by the type of construction, internal layout, and contents. The construction type determines the resistance of walls and floors to penetration by fire. The usual method for determining structural fire resistance consists of rating the performance of building materials and components when exposed to standard fire test conditions. The time-temperature relationship for the standard fire test is given by ASTM E-119.[1] This relationship provides a good means for determining the fire resistance of materials, since the general temperature levels over most of the curve correspond to magnitudes observed in actual building fires.

Customarily, the fire resistance rating of materials is expressed in terms of duration of exposure to the standard fire. Results of tests using this criterion are published by Underwriters Laboratories, Inc., National Bureau of Standards, and others. The British Department of Scientific and Industrial Research has also done considerable testing using a similar time-temperature relationship for the standard fire[(2)].

The traditional method of determining fire spread potential within a structure has been that of relating the combustible fire load (amount of combustible materials in pounds per square foot of floor area) directly with the fire resistance rating of structural materials. Low and moderate amounts of combustibles are said to increase the fire resistance requirements one hour for each ten pounds per square foot of loading. In this system, the rate of burning is taken to be constant at 10 pounds per hour per square foot of floor area, which corresponds to one particular situation. Since the burning rate controls the duration of fire, it should be used to appraise the adequacy of the fire resistance. The burning rate depends upon fuel surface and ventilation supply which, in turn, depends upon the building geometry and configuration of the combustibles.

The burning rate of common cellulosic materials under well-ventilated conditions has been determined to be a function of the fuel surface area. The work reported by Thomas[3], which included well-ventilated burning of 1/4 inch panels and dimensioned timbers, indicates that an average value for burning rates of wood during the peak fire is given by:

$$R_s = 0.09\ A_s \qquad (1)$$

where

$R_s$ = burning rate in lb/min.

$A_s$ = the exposed area of combustible surface in $ft^2$.

Recent work by Thomas[4] (in substantial agreement with other sources) demonstrated that the peak burning rate of a ventilation-controlled fire can be represented by:

$$R_v = 0.678\ A_w\ H_w \qquad (2)$$

where

$R_v$ = burning rate in lb/min.

$A_w$ = the area of the openings supplying ventilation ($ft^2$),

and $H_w$ = the height of these openings (ft).

In an average room, the transition from the burning of individual items to the burning of the whole room area occurs suddenly. This phenomenon is called flashover. Simultaneously with the flashover, the temperature of room rises rapidly from about 500°F to about 1500°F. If the start of flashover is interpreted to be the point where the standard time-temperature curve passes through 900°F, then a corresponding "zero" time with respect to flashover would be at the four minute mark.

The fire spread within structures was determined using this frame of reference for standard fire resistance ratings and the burning-rate equations. This was accomplished by considering the progress of the fire as a series of flashovers. The initial flashover was established for an area of about 100 to 150 square feet with subsequent flashover areas three times that of the immediately preceding area. This procedure is based upon observations of free burning building fires during the St. Lawrence burns.[5] It was assumed that each structure contained enough air by volumetric capacity plus infiltration to support a fire through the initial flashover. After flashover, only windows adjacent to the fire area were considered to provide ventilation to the fire. The dimensions of these window openings were used to evaluate the ventilation-controlled burning rate (Eq. 2). Equation 1 was used to determine the surface-controlled burning rate, and the lesser rate was used in determining the duration of peak fire in the location considered. In this respect, Thomas[4], Akita[6], and others have observed that approximately 50 per cent of the weight of combustible materials contributes to the peak fire. Accordingly, the duration of the peak fire has been taken to be one-half the ratio of the fire load to the burning rate.

The procedure for computing fire spread based on window ventilation is not valid for basements and similar windowless confinements. It would appear that such conditions result in fires with very long duration. This was confirmed by a calculation of burning rate based on the weight of air flowing through door cracks into the room[7] compared with the air needed for combustion of the fuel[8]. By this procedure, the burning rate in pounds per minute was found to be numerically equivalent to one hundredth of the crack length (ft) in a door leading to the fire area. The resulting burning rates gave fire durations exceeding at least 6 hours (see page B-4). A meaningful physical interpretation of the effect of this low burning rate on structural fire resistance is not now possible. Fortunately, the majority of such areas subject to such fires are designated as shelters. Study of fire spread in shelter areas is unwarranted; the treatment of fires in these areas should be considered in terms of extinguishment.

In the analysis of fire spread, the resistance of structural members has been interpreted to be the time necessary to penetrate the member and to flashover an area of 100 to 150 $ft^2$ on the unexposed side. As an example of the results, door ratings established by this analysis are given in Table II. It can be noted that the resistance to fire spread through a wall opening without a door has been given a non-zero value.

The approach described above was used to determine the spread of fire within shelter buildings. For this purpose, each structure was first subdivided according to the fire barriers present. Floors comprised the primary subdivisions, with the partitions within floor areas providing secondary subdivisions. Both subdivisions were analyzed regarding their

TABLE II

FIRE RESISTANCE RATINGS OF DOORWAYS ON A FLASHOVER TO FLASHOVER BASIS

| | Time-Minutes |
|---|---|
| Doorway, open | 5 |
| Tempered Glass | 26 |
| Wood Panel, 1" frame, 1/4" panel | 10 |
| Wood Panel 1-1/2" frame, 3/8" panel | 15 |
| Wood Hollow Core | 10 |
| Wood Solid Core, 1, 1-1/4" | 20 |
| Wood Solid Core, 1-1/2", 2" | 24 |
| Metal Door Ordinary Glass | 10 |
| Metal Door Wire Glass | 36 |
| Metal Door without Glass | 56 |
| U. L. Class "C" Door | 41 |
| U. L. Class "B" Door | 86 |
| U. L. Class "A" Door | 176 |

resistance to fire. This was accomplished by determining first the duration of the peak fire, according to the method discussed above. When the duration of the peak fire was less than the rating of the least fire-resistive member, fire was considered to have been confined within the subdivision. When the duration was found to be in excess of the rating, fire was considered to have spread through the barrier.

Distinction was made between direct penetration of floors and penetration into a shaft on one floor and out of the shaft on another floor. When both modes of penetration were found to exist, the one affording the least resistance was considered. Appendix B shows typical computation sheets for calculations of fire spread.

2. Spread of Smoke and Toxic Gases

With the multiplicity of variables and the number of situations involved in the buildings surveyed, no quantitative assessment could be made of fire-gas production. However, a relative comparison was made between buildings on the basis of features which tend to diminish fire gas concentration in the occupied areas. These features were determined from the following considerations.

The concentration of smoke and toxic gas reaching the shelter area depends upon a number of factors which in themselves are inter-related. These factors are: 1) fire duration and size, 2) the concentration of toxic gas generated in the fire area, and 3) dilution of fire gases and loss of buoyancy pressure along paths between fire area and shelter area. The following parameters can be specified for minimizing the spread of smoke and toxic gases:

a) small fire area,

b) small fire load,

c) large ventilation to fire area ratio,

d) small surface-to-weight ratio of the fuel,

e) few paths between fire and shelter area,

f) many barriers between fire and shelter, and

g) lack of vapor "tightness" in building construction.

Of the information available from the shelter survey and fire-spread calculations, the following conditions were found to reflect the above parameters:

1) fire spread limited to average partitioned area relates to items a and b,

2) ventilation sufficiently large for the burning rate to be fuel surface controlled reflects items c and d,

3) absence of minor openings, except at one central core, closed from the remainder of the floor, reflects item e, and

4) all stairs and elevators in shafts having doors at each level, signifies additional barriers specified in item f. No information was obtained concerning item g, tightness of building construction.

With all four conditions met, smoke and toxic gas levels in the shelter areas would not be expected to become critical. With three of four conditions exhibited, it would be expected that shelter occupants through make-shift sealing efforts from materials at hand should be able to prevent critical levels from being reached. With fewer than three of these conditions being met, special materials and devices would be needed for sealing shelter areas.

3. Fire Spread from Nearby Buildings

Potential ignition from burning adjacent structures can be determined from the level of radiant heat transmitted. This level was evaluated in terms of the minimum number of buildings opposing the shelter, that, when burning, would ignite the shelter building. For the purposes of this analysis, wood frame and masonry wall buildings were considered to be burning entirely at one time. Fire resistive buildings were considered to be burning a floor at a time.

The calculations were performed by using a flame area equal to twice the area of the windows on the floors being considered. This was done to compensate for floor penetrations and flame above the windows. Flame temperature was assumed to be 1800°F with an emittance of one. When the radiation level is sufficient for pilot ignition of exterior wood (0.4 $cal/cm^2$ sec), materials within the building are said to ignite.

4. Feasibility of Extinguishment

An important aspect for evaluating the vulnerability of a shelter building, is the determination of whether suppression of fires is feasible. Such predictions were made for the surveyed shelter buildings, assuming that in an occupied shelter sufficient manpower and portable extinguishers would be available. The consideration of fire suppression was limited to incipient fires, precluding fires of rapid build-up or in concealed or inaccessible spaces.

The determination of extinguishability in individual shelter buildings was made by engineering judgment with the assistance of project consultants. When portable means were found inadequate, the feasibility of suppression by fixed systems, such as standpipe and hose, and automatic sprinklers, was determined.

B. Results

1. Resistance to Interior Fire Spread

The resistances of the various types of surveyed shelter buildings to interior fire spread are summarized in Table III. The table shows, in each case, the maximum floor area which would be involved in a fire resulting from a single ignition. In order to show possible relationships between occupancy groupings and fire spread, buildings of wood joist construction, in which total fire spread will always occur, have been enumerated separately.

As seen from Table III, the first three occupancy groupings, schools and churches, offices and banks, and residentials exhibit the best fire resistant characteristics. This is a consequence of moderate combustible loadings, large window areas and a generally good degree of subdivision found in most of these types of occupancies. Where subdivision was lacking, as in churches, bank buildings and dormitory type residentials,

TABLE III

RESULTS OF FIRE SPREAD ANALYSIS

| | | | Area of Maximum Fire Involvement Resulting from One Ignition (Number of Buildings)* | | |
|---|---|---|---|---|---|
| Number | Type of Occupancy | Number of Wood Joist Structures or Additions | Average Partitioned Area | Entire Floor | Entire Building |
| 14 | Schools and Churches | 1 | 10 | 2 | 1 |
| 23 | Offices and Banks | 1 | 14 | 6 | 2 |
| 15 | Residentials | 3 | 8 | 3 | 1 |
| 3 | Telephone Exchanges | 0 | 0 | 2 | 1 |
| 5 | Garages | 0 | 0 | 2 | 3 |
| 2 | Post Offices | 0 | 0 | 0 | 2 |
| 2 | Libraries | 0 | 0 | 0 | 2 |
| 8 | Warehouses | 0 | 0 | 1 | 7 |
| 9 | Manufacturers | 1 | 0 | 5 | 3 |
| 5 | Publishers | 1 | 0 | 1 | 3 |
| 10 | Mercantiles | 3 | 0 | 0 | 7 |
| 6 | Theaters and Arenas | 1 | 0 | 0 | 5 |

* Excluding wood joist structures

fire would spread throughout the floor of ignition. In structures which have open stairways and a higher than average combustible fire loading, the fire would spread throughout the building. For example, this was observed in two offices which have mercantile occupancies on the first floor and open stairways, and in both a school and an apartment building having extensive combustible interior surfaces and open stairways.

Telephone exchanges have low combustible loadings, adequate windows and very little subdivision within the floor. The telephone exchange in which fire would spread beyond the floor of origin was an alarm office with unexpectedly large quantities of stored combustibles.

Post Offices and Public Libraries were found to be similar to the first three groupings of occupancies in Table III, except for the lack of subdivision within and between floor levels, and excessive quantities of combustibles. Fire would spread throughout these buildings where subdivision was lacking.

Warehouses typically have large quantities of combustibles, small window areas, and no subdivision of floor areas. Fire would spread through all except one of the surveyed warehouse buildings. The exception was a warehouse with sufficiently small quantities of combustibles (appliances in crates), and sufficiently large window areas, that floor opening protection was adequate.

Manufacturers and publishers have little subdivision of floor areas, large windows, most lacked protection of floor openings, and there was a wide variation in quantities of combustibles. A low combustible loading, such as was found in a cement plant, an electronics firm, and a cannery, would not result in fire spread throughout buildings even when the protection of floor openings was lacking. A moderate combustible loading and the lack of floor protection, however, would cause the involvement of the whole building. It was also determined in this case that the proper protection of floor openings would inhibit the spread of fire. Publishers have the largest combustible quantities so that even with very good protection of floor openings (encountered in one case), fire might not be limited to the floor of origin.

Fire would spread through mercantiles in all cases, as they were found to have undivided areas, substantial combustibles, and unprotected floor openings (usually escalators).

Theaters and arena buildings were found to have moderate combustible quantities, but fire spread would occur in all cases. This was the consequence of very little window access for fire ventilation and the general lack of opening protection.

2. Gas Spread Hazard

The problem of smoke and toxic gases was not considered in buildings in which fire would spread beyond the floor of origin. In these buildings, the extinguishment of fire is of primary concern which, when accomplished, would eliminate the threat from smoke and toxic gases.

Parameters minimizing the spread of smoke and toxic gases are reflected by the following four conditions: fire spread limited to an average partitioned area, ventilation sufficient for burning rate to approach fuel surface control, absence of minor openings, and all stair and elevator shafts having doors at each level. These conditions were considered for each shelter building where fire would not involve more than one floor level. Of some 43 shelters located in schools and churches, offices and banks, and residentials, 18 met all four conditions, 11 met three conditions, 10 met two conditions, 3 met one condition, and one met none. Fourteen other buildings considered included telephone exchanges, garages, a warehouse, manufacturers, and a publishing firm. Three of these structures met three conditions, 6 met two conditions, and 3 met one condition. Two not having combustible nonshelter areas were considered to meet all four conditions.

3. Frequency of Ignition from Nearby Structures

The level of heat radiation reaching the shelter building is determined by the size and construction of nearby burning structures, and their distance from the shelter building. For convenience, the buildings were categorized according to their location in the city. Individual shelter buildings were identified as located within: 1) the central portion of the principal business district, 2) adjoining nonresidential areas beyond the central district, or 3) residential areas beyond the central district.

The incidence of ignition of shelter building by nearby burning structures is given in Table IV. It shows the percentage of buildings in each location for which two or more nearby structures must be burning simultaneously to cause the ignition of the shelter building. The high percentage of shelter buildings in the central business district which would be ignited only by multiple ignition sources reflect the somewhat optimistic assumption that fire resistive buildings all burn one floor at a time. The number of sides that can be ignited by nearby structures are presented to give some indication of the magnitude of the effort required for ignition prevention or extinguishment.

4. Extinguishability in Surveyed Buildings

Extinguishment by means of portable extinguishers was considered feasible in 79 shelter buildings. Eleven structures were found to have concealed combustible spaces in their construction and two general storage warehouses have storage with sufficient bulk that access is greatly limited. Ten buildings were found where fire would rapidly build-up beyond the defined extinguishment limits. These include two clothing manufacturers, a hardware wholesaler with a large packing area, an upholstering firm, and a paper products manufacturer.

TABLE IV

SHELTER BUILDINGS IGNITABLE BY NEARBY BURNING STRUCTURES

| Shelter Building Location | Number of Buildings | Buildings Ignitable | Per cent of Building Ignitable Needing Multiple Ignition Sources* | Number of Sides of Ignitable Building Facing Ignition Sources | | | |
|---|---|---|---|---|---|---|---|
| | | | | One | Two | Three | Four |
| In central business district | 36 | 21 | 43 | 11 | 6 | 3 | 1 |
| Adjoining nonresidential areas beyond central district | 38 | 18 | 22 | 8 | 9 | 1 | 0 |
| Within residential areas beyond central district | 28 | 10 | 10 | 4 | 3 | 3 | 0 |

* An ignition source is taken to be one burning adjacent building.

A significant number of the shelter buildings surveyed have either substantially complete automatic sprinkler equipment or standpipe and hose systems, supplied in most cases from public water mains. Of the 23 buildings not considered extinguishable by portable appliances, 12 are equipped with at least one of these types of systems and two also have a self-contained supplementary water supply. Included among these are the five garages where explosion or health hazards due to hycrocarbon vapors would not be eliminated by the extinguishment system.

5. Effect of Shelter Supplies on Peacetime Fire Potential

The storage of supplies in shelter buildings was found to be concentrated in either one central location for the entire building or apportioned on each floor having a shelter area. The use of basement storerooms is quite common, particularly in buildings of multiple tenancy. In warehouses and factories, the supplies are frequently found in the open alongside of stock.

The ignitability of these supplies is equivalent to that of heavy cardboard cartons and fiber drums in normal floor to ceiling stocking. The combustible quantity was calculated, from the individual supply requirement, to be 1.7 pounds per person excluding 5.2 pounds per person of crackers stored in tins. The effect on the total average fire load would be an increase of 0.207 $lb/ft^2$ in basement areas and 0.17 $lb/ft^2$ on upper floors. These values were calculated for an eight foot high basement with the shelter volume requirement of 500 cubic feet of space per person, and for upper floor shelters providing ten square feet of floor area per occupant.

It has been found that in occupancies without bulk storage, high concentrations of combustibles must cover at least 100 $ft^2$ floor area to be considered as constituting a significant fire loading[9]. Hence, the hazard from local concentrations of shelter supplies can be considered to exist only where the shelter area supplied from this storage location is quite large. With shelter stocks piled 8 feet high, the 100 $ft^2$ limit for local storage concentrations is exceeded only when below ground sheltersare greater in area than 120,000 square feet, and above ground, greater than 19,000 square feet. Thus, in most cases, the blocks of combustible shelter supplies will be automatically limited to less than 100 square feet when the shelter supplies are located on each floor having a shelter area.

Therefore, when local concentrations of shelter stocks are limited in area, there is no significant contribution to the existing combustible fire load.

6. Special Problem of Parking Garages

Parking garages, especially those of the underground type, offer potentially excellent use as fallout shelters due to their construction, large floor area, and absence of exterior wall openings which might be exposed to the thermal pulse or to adjoining burning buildings. However, the customary presence of large numbers of automobiles within these types of buildings introduces two serious problems.

A British study[10] indicates that the maximum human tolerance to gasoline vapors is 0.007 gram per liter (1500 ppm). Patty[11] indicates that a 200 ppm concentration will cause dizziness and anesthesia after one hour. He also indicates that 500 ppm is the threshold for toxic reactions to gasoline in long time exposures. The use of a parking garage for shelter purposes will certainly necessitate the provision of adequate mechanical ventilation facilities with a reliable secondary means of power contained within the building.

From a fire-hazard standpoint, the combustible fire load of a parking garage is comparatively low, approximately 2-4 $lbs/ft^2$. Nevertheless, the fire hazard and spread potential resulting from the presence of numerous small tanks of gasoline coupled with the existence of open ramps throughout the building make it imperative that extreme care be taken to avoid the possibility of any ignitions taking place during shelter occupancy. Fortunately, most parking garages are fully sprinkled, as was verified in the cases of the five garage occupancies involved in the shelter survey program. Where utilized for shelter purposes, a secondary self-contained water supply should be provided to increase the reliability of the sprinkler system under emergency conditions. Also, an adequate number of dry chemical type portable extinguishers should be provided in addition to conventional water pump types for use by shelter fire fighting personnel.

## IV. CONCLUSIONS

### A. Characteristics of Fallout Shelter Buildings

Based on information gathered from 102 buildings selected as representative of those available in the 24 cities initially having stocked fallout shelter buildings, the following conditions are considered characteristic:

1. Fire resistive construction will be prevalent, although some unprotected steel and masonry wood joist structures may be found. Principal floor openings will generally be enclosed, but enclosures may be lacking in some localities.

2. The normal occupancies of most shelter buildings will consist of those types generally found in commercial and public buildings.

3. Significant numbers of portable extinguishers are to be found in a majority of buildings. Standpipe and hose installations are less often available. Automatic sprinkler systems are found for the most part only in particular types of occupancies.

4. Generally, fewer shelter areas will be found aboveground than below ground. However, the majority of the shelter population will be in above-ground shelters.

### B. Fire Vulnerability of Shelter Buildings

Analysis of survey shelter buildings revealed varying degrees of vulnerability in one or more of the following five fire-safety aspects:

1. Fire would be contained within the floor of origin in fire resistive structures in several occupancy groupings. Schools, churches, offices, banks, residentials, and telephone exchanges would resist fire spread either when a good degree of subdivision exists within each floor, or when all floor to floor openings are protected. Manufacturing buildings with low combustible loading (1-3 pounds per square foot), and those with moderate loading having protected floor openings would also resist the spread of fire.

2. Well-subdivided structures capable of preventing fire spread away from the floor of origin would require only minimum efforts by occupants to prevent smoke and toxic gases from reaching dangerous levels. When such structural characteristics are lacking, special equipment and materials must be employed by occupants to effectively minimize the spread of smoke and toxic gases.

3. Approximately two-thirds of the surveyed buildings in "downtown" areas and one-third of those in exclusively residential areas were exposed to ignition from nearby burning structures. Approximately one-half of all buildings exposed to ignition from adjacent buildings could be exposed on more than one side.

4. With few exceptions, fire suppression by shelter occupants could be effectively accomplished with sufficient portable extinguishers. Properly supplied standpipe and hose or automatic sprinkler systems will control fire in those

exceptional occupancies where rapid fire buildup is characteristic, or where access to combustibles is prevented by considerable bulk storage or concealed combustible building construction.

5. The contribution of shelter stock to the peacetime fire severity of shelter buildings is significant only when storage of the combustible portion of these supplies exceeds 100 square feet of floor area and when the normal-occupancy fire loading is relatively light. Such conditions occur when stocks for large shelter areas located on several above-ground floors are stored in one location. In most cases, combustible shelter supplies will occupy less than 100 square feet when the shelter area and its supplies are located on the same floor.

## V. OPERATIONAL GUIDANCE FOR SHELTER SELECTION AND UPGRADING

### A. Levels of Fire Vulnerability

The criteria for the selection of new fallout shelter buildings and the upgrading of existing facilities should include the relative degree of fire vulnerability, as well as the ability to protect against fallout. It was shown in previous analyses that an ignition in the shelter building could be satisfactorily controlled through containment of fire in a portion of the building by means of structural fire resistance or through rapid discovery and extinguishment by shelter occupants. Preference should be given to buildings with fire containment structural characteristics as the safety of fallout shelters in these structures is less dependent upon the activity of occupants. However, reliance on fire extinguishment will give favorable results when occupants are adequately organized, equipped, and trained for fire fighting and where these activities are not curtailed by nuclear radiation. The order of preference is given below using shelter building categories developed in the previous analyses.

1a) Fire Limiting - No combustibles outside shelter areas.

1b) Fire Limiting - Fire gases controllable without special means.

1c) Fire Limiting - Fire gases controlled with special means.

2 ) Suppression Dependent.

3a) Untenable - Fire not controllable with portable extinguishers.

3b) Untenable - Problem other than extinguishment.

1. Fire Limiting

Fire limiting buildings are those in which fully developed fires orginating outside shelter floors will not progress to these floors. The analysis indicates that shelter buildings resisting the spread of direct fires would mainly include those used as schools, churches, offices, banks, residential types, telephone exchanges, and manufacturers with low combustible contents loading. A method for selection of fire limiting buildings is presented in Appendix C.

As the resistance to direct spread of fire does not preclude possible spread of smoke and toxic gases, this characteristic of Fire Limiting buildings must be determined separately.

2. Suppression Dependent

This intermediate fire vulnerability level denotes those instances where fire spread cannot be adequately resisted by the building members, but it is possible to extinguish all incipient fires using portable extinguishers. This level includes all buildings not specifically falling in either of the other two categories.

3. Untenable

This fire vulnerability level consists of buildings where extinguishment of fire using portable equipment is considered unfeasible due to excessively rapid fire buildup, or concealed or inaccessible combustibles. Identification of buildings having these characteristics can be made from the following illustrative situations.

a) Buildings where explosive vapors or dusts may be present such as automobile garages and certain types of industrial occupancies.

b) Buildings with significant accumulations of wood scraps, paper, and textiles.

c) Buildings having contents storage such that combustible stock piles are high and/or with the absence of adequate aisle space between adjacent piles.

d) All buildings of masonry and wood joist constructions, as in these structures concealed and inaccessible combustible spaces predominate.

## B. Acceptability Criteria

The following factors should be considered in evaluating the potential acceptability of a building for fallout shelter use:

1) Buildings of all fire vulnerability levels must be free from severe exposure to ignition from nearby structures. As a guide to such determinations, the method of calculating building separations by Margaret Law(12) can be used.

2) Buildings of all vulnerability levels should be protected from ignition by the thermal pulse of the nuclear weapon insofar as possible.

3) Buildings of all vulnerability levels should be provided with adequate portable fire extinguishing equipment.

4) Special facilities should be provided for controlling fire gases in Fire Limiting buildings where this need has been determined.

5) Access within Suppression Dependent buildings should not have to be limited (by nuclear radiation) to intervals so short that fire discovery and extinguishment efforts will be curtailed. A minimum shielding value, possible a protection factor of at least 100, should be selected as a criteria.

6) Untenable shelter buildings should be provided with adequate and properly supplied fixed extinguishment systems.

7) Untenable buildings where toxic and flammable vapors are found, principally automobile parking garages, should be supplied with reliably-powered mechanical ventilation equipment.

C. <u>Upgrading Shelter Buildings</u>

1. Reducing Spread of Smoke and Toxic Gases

The extent to which smoke and toxic gases can spread through a building, as has previously been indicated, is dependent in part on its interior configuration, the degree to which it is subdivided by partitions and doors, and the extent to which its various floor openings are protected. Therefore, it is possible to reduce this hazard through structural alterations, especially in those portions adjacent to shelter areas.

In any case, shelter areas themselves must be sealed off from the remainder of the building in a manner sufficient to exclude smoke and toxic gases. This will necessitate the grouting of any wall or floor openings around ducts or piping which pass through the shelter area and the sealing of any cracks or openings around doors leading into the shelter area after it has been occupied. In addition, provisions should be made to seal all supply or exhaust openings in air ducts within the shelter area if the need arises.

2. Reducing Fire Spread

It is not expected that all shelter buildings classed as Suppression Dependent can reasonably be upgraded to a better classification because of operational space and traffic needs inherent in certain types of occupancies.

Improvement of interior barriers to fire in buildings selected as shelters would most often take the form of strengthening doorways. For example, in the five deficient buildings indicated in the first four occupancy groupings in Table III, the provision of doors to protect stairwell openings would enable these buildings to qualify as Fire Limiting.

A structure having deficient ventilation may be improved by providing automatic fire vents at the top of stairwell and elevator shafts.

To aid in making judgments as to necessary minimum improvements, a numerical system for the assessment of shelter fire spread, presented as Appendix C, is recommended. This is an empirical method developed for identifying buildings which should class as Fire Limiting.

3. Protection against External Fire Exposure

Means for shielding exterior windows against the penetration of radiant heat energy should be provided both for protection from nuclear weapons and nearby burning structures. Such protection is necessary for all shelter buildings, but is especially important in Suppression Dependent buildings where numerous ignitions would become impossible to extinguish. The protection from nearby buildings can be limited to walls facing such buildings, while protection from the thermal pulse will be necessary for all windows from which the sky can readily be observed. The window shielding may take the form of either a pre-installed device such as a reflective screen or as a coating applied in the emergency or a combination of both. A more substantial means, such as outside sprinkler protection, may be needed where exposure from nearby buildings is severe.

4. Portable Fire Extinguishers

Current NFPA standards(13) recommend one 2-1/2 gallon water type extinguisher (or equivalent) for each 2500 square feet floor area in normal hazard occupancies, for fires in ordinary combustible materials such as wood, cloth, paper, etc. In light hazard occupancies, i.e., office buildings, schools, etc., the allowable floor area is doubled. The five-gallon stirrup pump extinguisher, considered equivalent to two of the above extinguishers, has been found to be the most satisfactory type.(14) The requirements for portable"extinguishability" as set forth in Section III A4 of reference 14 are as follows: Each occupied shelter area should be provided with a minimum of four 5-gallon stirrup pump extinguishers plus one additional for each 1250 square feet of shelter area in excess of 5000 square feet. Nonshelter areas of Suppression Dependent buildings should be provided with one stirrup pump extinguisher for each 2500 square feet of floor area and nonshelter areas of Fire Limiting buildings should be provided with one for each 5000 square feet. In nonshelter areas, existing 2 1/2-gallon Class A extinguishers installed for normal use may be accepted in lieu of stirrup pumps on a two for one basis. The above requirements may be halved in "light hazard" occupancies. The survey indicated that, in most buildings, special extinguishers are already installed where needed for flammable liquid or electrical fire hazards (Class B or C Fires).

5. Fixed Extinguishment Systems

Standpipe and hose and automatic sprinkler systems with adequate and reliable water supplies can be installed in shelter buildings which would otherwise be classed as untenable due to large contents bulk or rapid fire build-up. Sprinkler systems also have the advantage of functioning in areas where access by personnel is limited by fallout.

Present NFPA standards for standpipe and hose systems for occupants use[15] provide that not over 75 foot lengths of 1-1/2" hose be used at each hose station and that they be spotted so as to reach to within 20 feet of every point in the building.

Where it is determined that a public water system would not provide a reliable fire protection supply for sprinkler or standpipe and hose systems under attack conditions, a private self-contained supply in the form of a pressure tank or some equivalent means should be provided within the shelter building.

## VI. FALLOUT SHELTER BUILDING CODE CRITERIA

This discussion is intended to cover only those building code features relating to fire safety. Considerations such as sanitation, ventilation, portable water supplies, and radiation shielding will be treated to the extent that they influence the fire hazard characteristics of the building. Also, shelter equipment, such as emergency power supplies and oxygen regenerators, has not been included within the scope of this discussion. Nevertheless, it is assumed that the design and installation of these special devices will include strict limitations upon hazardous features. Although specific code provisions are set forth in some instances, this discussion is primarily intended to provide background material for use in development of specific building code provisions.

### A. Basic Requirements

The effects of a nuclear attack on buildings constructed under peacetime fire safety requirements was explored in the analysis of fallout shelter buildings. Under conditions of nuclear fallout, buildings suffering little blast damage must nevertheless be capable of withstanding fire and fire exposure to the extent that occupants can remain in protected portions of the building without outside aid from professional fire fighters. The only manner in which fire safety conditions can be provided for fallout shelters under nuclear attack is through adequately meeting all of the following considerations:

1. Self-help fire fighting measures on the part of occupants will be necessary and must be aided through a) restrictions on combustible interior finish, b) restrictions on combustible contents, and c) provision of extinguishment facilities.

2. Structural fire resistance must be sufficient to resist the spread of fire, smoke, and toxic gases for the total length of fire duration.

3. Adjacent buildings should be separated by sufficient clear space that, commensurate with window shielding, ignitions of shelter structures caused by fire in these buildings can be prevented or easily suppressed.

4. Some means of shielding should be provided for exterior windows which will minimize the potential ignition of interior contents from the thermal pulse of a nuclear weapon.

5. Adequate means of ingress must be provided within shelter buildings so as to permit rapid initial access to each shelter area. In addition, consideration must be given to the need for shelter occupants to have a safe means of access to other parts of the shelter building when internal fire fighting efforts become necessary.

B. <u>Method of Code Application</u>

The development of specific code criteria for shelter buildings should take into account the difficult problems which can arise in attempting to regulate existing (pre-ordinance) buildings and the need not to discourage property owners from utilizing their buildings for shelter purposes. Therefore the following distinction should be made for purposes of establishing requirements: 1) existing buildings having secondary use as shelters, and 2) new buildings having secondary use as shelters.

Requirements for existing buildings should represent the minimum standards necessary for acceptance for shelter use and should allow buildings of both Fire Limiting and Suppression Dependent levels of fire vulnerability.

The application of code requirements to new buildings, which will have some secondary shelter use, should permit the use only of buildings classifying as Fire Limiting.

It is assumed that the design of new buildings intended primarily for use as shelters will encompass blast resistance and other protective features considerably in excess of those feasible in buildings having only secondary shelter use and therefore this category has been omitted from the scope of this discussion.

C. Specific Code Provisions

Table V outlines the various fire safety design features which should be regulated by means of building code requirements in order to insure the safety of shelter occupants during their necessary period of confinement.

D. Recommendation

Specific building code provisions for fire safety of fallout shelters should be developed from the material in Table V.

TABLE V

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Fire resistance of w[illegible], floors, roof [illegible] their supp[illegible] | Minimum 2 hours (see Note 1) | Minimum 2 hours except 3 hours for primary floor and roof supports (see Note 2) |
| Protection of vertical openings | 1 hour | 2 hours (see Note 2) |
| Interior finish (see Note 3) | Flame spread of not greater than 25 in shelter areas; 200 in other parts of building | Flame spread of not greater than 25 in shelter areas; 75 in other parts of building |
| Exterior wall openings | Provide some means of shielding to protect from the thermal pulse of a nuclear weapon | (1) Provide some means of shielding to protect from the thermal pulse of a nuclear weapon.<br>(2) Provide approved wired glass in metal frames in any opening exposed by an adjacent building. |

TABLE V (cont)

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Resistance to spread of smoke and toxic gases | Physically separate each shelter area from remainder of building with walls and tight fitting doors of required fire resistance | (1) Physically separate each shelter area from remainder of building with walls and tight fitting doors of required resistance<br>(2) Provide maximum interior compartmentation on each floor level throughout the building with emphasis on floor levels housing shelters<br>(3) Air duct systems should be arranged so as to minimize the possible transfer of smoke and toxic gases into any shelter area. |
| Ingress facilities (see Note 4) | Provide sufficient ingress facilities from the outside to each shelter area, on the basis of 150 persons per 22" unit of stairway width and 200 persons per 22" unit of door width, so as to be able to adequately handle the entire rated shelter capacity | Provide sufficient ingress facilities from the outside to each shelter area, on the basis of 150 persons per 22" unit of stairway width and 200 persons per 22" unit of door width, so as to be able to adequately handle the entire rated shelter capacity. |

TABLE V (cont)

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Portable fire extinguishers | Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 1250 square feet of shelter area with a minimum of 4 extinguishers per shelter<br>Non-Shelter Areas - provide one unit of extinguishing capacity for each 1250 square feet of floor area. Where the existing complement of extinguishers is inadequate, supplement these specifically with the installation of 5-gallon stirrup pump type extinguishers on the basis of 5000 square feet per extinguisher | Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 1250 square feet of shelter area with a minimum of 4 extinguishers per shelter<br>Non-Shelter Areas - provide one 5-gallon stirrup pump type extinguisher for each 5000 square feet of floor area |

TABLE V (cont)

RECOMMENDED BUILDING CODE PROVISIONS FOR SHELTER BUILDINGS

| Feature | Requirements for Existing Buildings | Requirements for New Buildings |
|---|---|---|
| Combustible contents | Highly flammable contents such as combustible fibers (cotton, jute, sisal, etc....), flammable liquids, hazardous chemicals, dusts, etc.... shall not be permitted within the building except in nonshelter areas and then only if separated from all other portions of the building by walls, floors and doors having adequate fire resistance and if stored in accordance with nationally recognized standards of safe practice. | Shelter Areas - combustible contents should be restricted to that necessary in connection with operating the shelter in an emergency<br><br>Non-Shelter Areas - highly flammable contents such as combustible fibers (cotton, jute, sisal, etc....), flammable liquids, hazardous chemicals, dusts, etc... should not be permitted within the building. In addition, the maximum permissable combustible fire load for any floor level should not exceed an average of 15 pounds per square foot of floor area. |

NOTES:

1. An existing building having structural components of less than 2 hours fire resistance may be accepted if, in the opinion of the enforcing authority, its occupancy, interior configuration, etc., is such as to enable it to be classed as Suppression Dependent.
2. Where the anticipated combustible fire load of a building is less than 10 $lbs/ft^2$, the required fire resistance for primary floor and roof supports and vertical opening protective assemblies may be reduced to 2 hours and 1 hour respectively.
3. Flame spread ratings are based on the A.S.T.M. E-84 Tunnel Test method.
4. Capacity of ingress facilities is based upon half of the egress facilities normally required for an assembly type occupancy by the N.F.P.A. Building Exits Code and ideally permits the last person to reach the shelter area 3-1/2 minutes after the first person passes through a shelter area doorway. Although facilities would be considered inadequate from a peacetime egress standpoint, it must be recognized that "emergency" egress under post-attack conditions would probably be pre-planned and carefully controlled. In addition, the application of normal exit capacity requirements to most shelter ingress situations would produce prohibitive requirements in all except shelter buildings having a peacetime assembly occupancy.

## VII. FUTURE STUDY

### A. Shielding Windows against Radiant Ignition

In an attack situation, fallout shelter buildings are subject to two potential outside sources of ignition. The first is direct ignition by the thermal pulse. The second is ignition by burning adjacent structures. Secondary ignitions resulting from weapon blast damage can be ignored as the overpressure levels required would also render such buildings unfit for fall-out protection. Therefore, a considerable reduction in shelter building ignitions can be accomplished by limiting the radiant heat energy which may penetrate into the building.

Recommendation: The effect of various possible types of window coverings and coatings should be investigated to determine their ability to resist both kinds of radiating sources. Relative costs, availability and ease of application should be considered in selecting materials.

### B. Implementation of Shelter Building Selection Criteria

This report has made definite proposals concerning the selection techniques which should be used in choosing and upgrading potentially fire-safe buildings for fallout shelter use.

Recommendation: A small city requiring approximately one hundred shelter buildings should be surveyed to determine the degree with which potentially fire-safe shelter buildings can be located, the relative amount of up-grading which must be performed, the degree of acceptance by property owners, costs involved, etc.

C. Generation and Spread of Smoke and Fire Gases within Shelter Buildings

This report has discussed various structural features which bear on the problem of limiting the spread of smoke and fire gases within shelter buildings. However, presently available information on this subject is not adequate to accurately predict the quantities of smoke and gases generated, the degree of penetration of various combustion products throughout buildings, the performance of conventional structural barriers in restricting smoke and gas flow over extended periods, and the effects of variables such as ventilation, building configuration and type of combustibles.

Recommendation: Experimental studies should be conducted for the purpose of developing realistic fire safety criteria for shelter building design.

## REFERENCES


1. National Fire Protection Association Standard No. 251, "Standard Methods of Fire Tests of Building Construction and Materials," May 1961, (ASTM E-119).

2. British Standard 476 - "British Standard Specification for Fire Tests on Building Materials and Structures," 1953.

3. Thomas, P. H., Department of Scientific and Industrial Research and Fire Officers Committee, Fire Research 1958, p 11 and 12.

4. Thomas, P. H., "Studies of Fires in Buildings Using Models, Part I Experiments in Ignitions and Fires in Rooms, Part II Some Theoretical and Practical Considerations," Research, Feb., March 1959.

5. Shorter, G. W., J. H. McGuire, M. B. Hutcheon and R. F. Leggett, "The St. Lawrence Burns," Quarterly of N.F.P.A., Vol. 50, No. 4 pp. 300-316, April 1960.

6. Akita, K.,"Studies on the Mechanism of Ignition of Wood," Report of the Fire Research Institute of Japan, Vol. 9, No. 1-2, March 1959.

7. ASHRE Guide and Data Book 1961, Chap. 24,p. 425, Table 3.

8. Private communication with Willis G. Labes, Professor of Fire Protection Engineering, IIT.

9. Joint British Fire Research Committee, Post War Building Studies No. 20, "Fire Grading of Buildings, Part I - General Principles and Structural Precautions."

10. Post War Building Studies No. 28, "Precautions Against Fire and Explosion in Underground Car Parks," 1950.

11. Frank A. Patty, Editor, "Industrial Hygiene and Toxicology" Vol.II, p. 1200, 1962.

12. Department of Scientific and Industrial Research and Fire Officers Committee, Fire Research Special Report No. 2, "Heat Transfer by Radiation," 1953.

13. National Fire Protection Association, Standard No. 10, "Standard for the Installation, Maintenance and Use of Portable Fire Extinguishers," 1964.

## References (Cont)

14. Salzberg, F., G. L. Maatman and F. Vodvarka, "An Approach to Trans-Attack Fire Suppression in Urban Areas", Final Report, OCD-OS-62-210, March 1964.

15. National Fire Protection Association, Standard No. 14 "Standard for the Installation of Standpipe and Hose Systems," 1963.

# APPENDIX A

## SAMPLE SURVEY - DEPARTMENT STORE

The following eleven pages are presented as representative of the information sought and obtained from the shelter surveys. They include a summary, information and diagrams of the general building characteristics, both above ground and below ground shelter areas, and features of the surrounding areas. Excluded were pages pertaining to other shelter areas and photographs taken in and around the shelter building.

## SUMMARY

Shelter building is of fire resistive construction, reinforced concrete, containing seven stories and two basements with a ground floor area of 42,000 square feet.

It is an all-sprinklered building with sprinkler equipment fully in service. Single source water supply consisting of three, 6" connections to 20" city water mains. Inadequate number of portable extinguishers.

Floors and ceilings are 4" reinforced concrete on ribs 18" to 24" deep and 20" wide. Stair and elevator shafts are 6" concrete.

Passenger elevators are closed at each level by 1-1/2" flush metal doors, hollow core; freight elevators closed at each level by 1-1/2" metal panel doors.

Stairs are closed at all levels with 1-3/4" metal panel doors except those leading to streets which are closed with 1-3/4" metal frame, glass doors.

In addition to Department Store, building also contains office space and K-- radio equipment room. Two radio towers are on roof of the building. Occupancy hazards are occasional spray painting and power woodworking and gas cooking.

No unusual exposure from nearby building.

# SHELTER FIRE PROTECTION SURVEY FORM A

Sheet 2 of 21

Building Name and Address: ANYTOWN DEPARTMENT STORE
City and State: ANYTOWN, ALLSTATE Tract: 57 Facility: 0/432
Building Owner: H. JONES PV Code: 55 Use Code: 44
Person to Contact: SAME

Date: JAN. 1, 1963
Surveyor: J. DOE

## BUILDING HOUSING SHELTER

I. BUILDING DESCRIPTION

a. General age: 26 b. Ground floor area: 42,500 c. Height (no. of flrs.) 7(96')

d. Construction type(s) (% of each if mixed): Reinf. conc. X Prot. steel ___ Unprot. steel ___

Heavy timber ___ Wood joist ___ Frame ___ Other ___

e. Wall Material (% of each): CONCRETE

f. Exterior wall openings (% of wall area in openings)
Street floor: N 10 S 0 E 0 W 60
Typical upper floor: N 30 S 0 E 30 W 30

g. Protection of floor openings (Stairways, elevators, ducts, utility core):

h. Building equipment and utilities
Number and distribution of air conditioning systems:
AIR CIRCULATION FROM FAN ROOMS IN BASEMENT.
Heating and fuel arrangements: STEAM, PIPED IN FROM PLANT OUTSIDE BUILDING; ALSO HOT AIR FROM HEAT EXCHANGER IN FAN ROOM.
Type and location of inside transformers:
NONE

j. Remarks:

II. OCCUPANCY (Except Shelter Area Floor)

a. General Class (Indicate whether premises filled or crowded): DEPARTMENT STORE (FILLED)

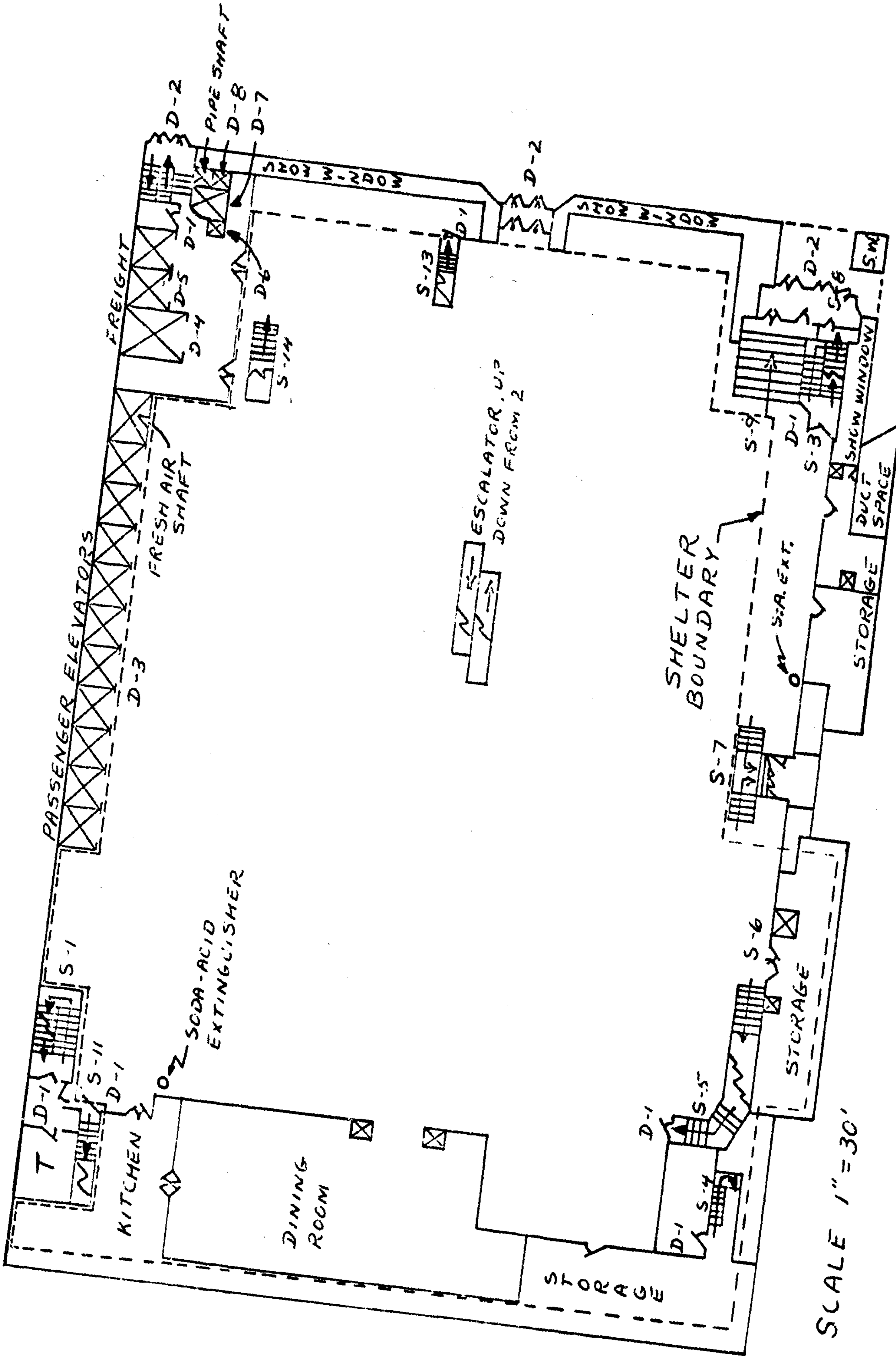
b. Special uses: RADIO TRANSMISSION, TOWERS ON ROOF.

c. Mfg. or process equipment:

d. Storage (Mdse., materials, etc.):
MERCHANDISE IN BASEMENT AND 6th FLOOR

e. Remarks:

III. PLAN VIEW OF STREET FLOOR (Use reverse side).




FIRST FLOOR

SCALE 1"=30'

## SHELTER FIRE PROTECTION SURVEY FORM B



Building Name and Address: ANYTOWN DEPARMENT STORE Date: JAN. 1, 1963
City and State: ANYTOWN, ALLSTATE Surveyor: J. DOE

FLOOR ON WHICH SHELTER AREA LOCATED--STRUCTURAL
(Use one sheet for each floor having a shelter area)

Floor: BASEMENT

IV. PHYSICAL DESCRIPTION

a. Floor area: 36,720 b. Shelter capacity: 1940 c. Shelter area: 36,720 d. Ceiling height: 12'

e. Material used for finish of interior:

f. Structural separation of shelter area:

g. Protection of floor openings (other than to shelter area if area separated structurally):

V. OPENINGS INTO SHELTER AREA (Include floor opening protection when shelter not separated):

a. Door openings

| | Purpose | Width | Height | Direction (in/out) | Door Const. | U. L. Class | Single / Dbl. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1. | STAIRS 1,2,5,8,13 | 3' | 7' | OUT | METAL | -- | SINGLE | 1-3/4" METAL PANEL DOORS |
| 2. | PASS. ELEVATORS D2 | 5' | 7' | SLIDING | METAL | -- | SINGLE | 1-1/2" METAL, FLUSH, HOLLOW CORE |
| 3. | FRT. ELEVATOR D3 | 8' | 7' | UP/DOWN | METAL | -- | SINGLE | 1-1/2" METAL, PANEL DOOR |
| 4. | FRT. ELEVATOR D4 | 6' | 7' | UP/DOWN | METAL | -- | SINGLE | 1-1/2" METAL, PANEL DOOR |
| 5. | FAN ROOM D5 | 2'8" | 6'8" | IN/OUT | METAL | -- | DOUBLE | 1-3/4" METAL, FLUSH, HOLLOW CORE |
| 6. | STAIRWAY S12 | 2'6" | 6'8" | OUT | METAL | -- | SINGLE | 1-3/4" METAL PANEL DOOR |
| 7. | FRT. ELEVATOR D10 | 8' | 8' | UP/DOWN | METAL | -- | SINGLE | 1-1/2" METAL PANEL DOOR |

b. Other openings (Access panels, holes, pipes, chases, ducts, drains, etc.) Describe:

D-7 PAPER CHUTE 2'X3' HINGED METAL DOOR, 1-1/2" THICK
D-8 SPIRAL CHUTE 3'X3' METAL DOOR, 1-1/2" THICK
D-9 DUMB WAITER 2'6"X3' METAL DOOR, 1-1/2" THICK
S-14 STAIRWAY OPEN AT BASEMENT AND 1ST FLOOR LEVEL

c. Remarks:

AIR DUCTS HAVE DAMPERS

VI FIRE PROTECTION EQUIPMENT--Describe and locate:

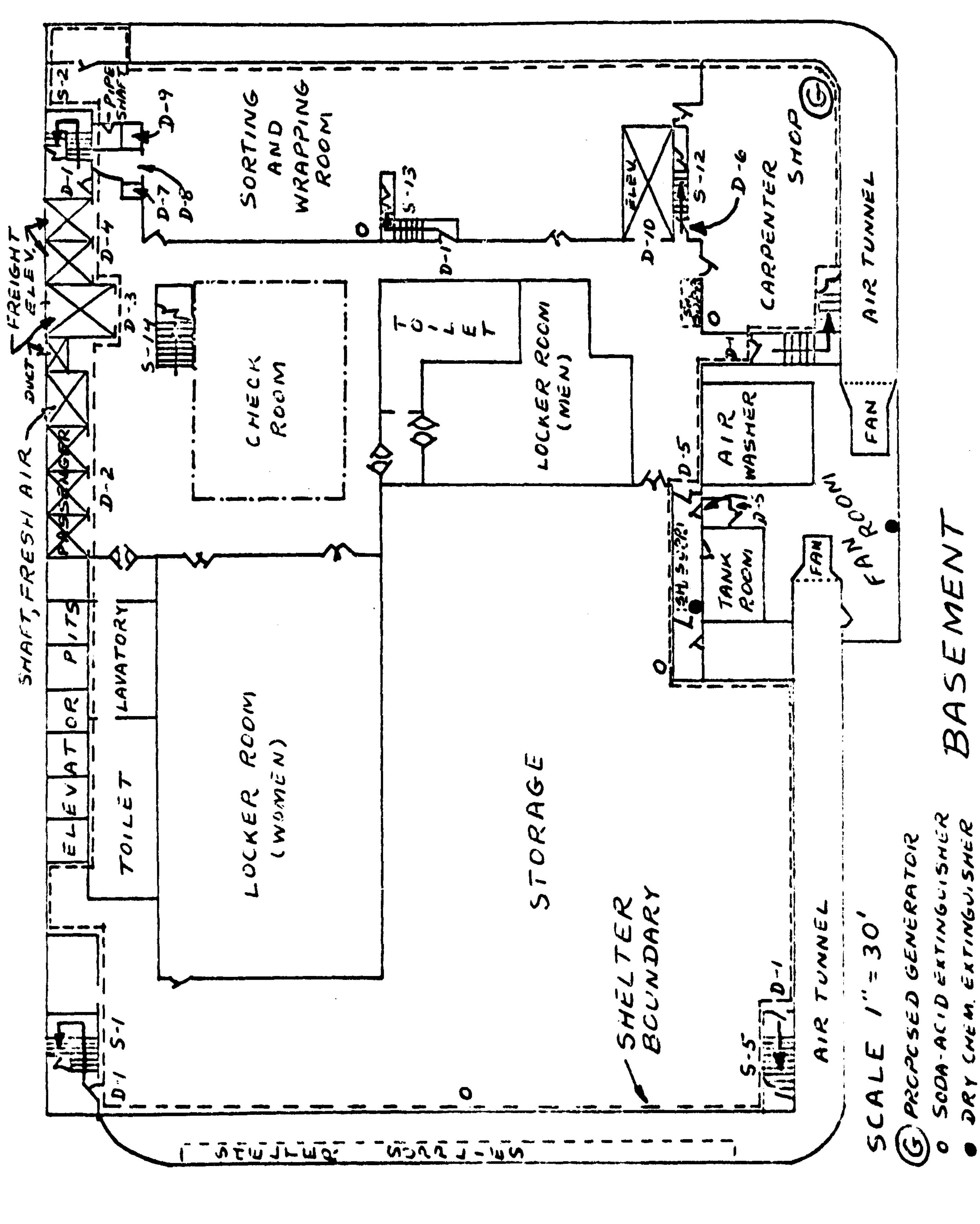
a. Portable extinguishers: SODA-ACID AND DRY CHEMICAL - AS SHOWN

b. Small hose on standpipe: NONE

c. Fixed extinguishing systems:

d. Remarks: ENTIRE AREA COVERED WITH AUTOMATIC SPRINKLERS.

VII. PLAN VIEW OF FLOOR (Show on reverse side; scale not smaller than 1 inch = 50 feet.)



BASEMENT
SCALE 1" = 30'
G PROPOSED GENERATOR
○ SODA-ACID EXTINGUISHER
● DRY CHEM. EXTINGUISHER
SORTING AND WRAPPING ROOM
CARPENTER SHOP
AIR TUNNEL
FAN
AIR WASHER
TANK ROOM
FAN ROOM
LOCKER ROOM (MEN)
TOILET
CHECK ROOM
LOCKER ROOM (WOMEN)
STORAGE
SHELTER BOUNDARY
LAVATORY
ELEVATOR PITS
SHAFT, FRESH AIR
DUCT
PASSENGER
FREIGHT ELEV.
ELEV.
PIPE SHAFT
SHELTER SUPPLIES
D-1
D-2
D-3
D-4
D-5
D-6
D-7
D-8
D-9
D-10
D-11
S-1
S-2
S-5
S-12
S-13
S-14

SHELTER FIRE PROTECTION SURVEY FORM C

Sheet: 7 of 21

Building Name and Address: ANYTOWN DEPARTMENT STORE    Date: JAN. 1, 1963
City and State: ANYTOWN, ALLSTATE    Surveyor: J. DOE

FLOOR ON WHICH SHELTER AREA LOCATED -- CONTENTS
(Use one sheet for each floor having a shelter area)

Floor: BASEMENT

| VIII. OCCUPANCY | | Description | Floor area Size or % of total | Occu. Density (sparse, avg., congested) | Location with respect to and separation from shelter area (See IVf and V on Form B) |
|---|---|---|---|---|---|
| a. Equipment and Utilities | Mfg. or Process | SORTING + WRAPPING RM. | 3,800 S.F. | | PART OF SHELTER AREA |
| | | CARPENTER SHOP | 1,800 S.F. | | PART OF SHELTER AREA |
| | Bldg. Service | FAN ROOM | 2,000 S.F. | | ADJACENT |
| | | SWITCH BOARD | 240 S.F. | | ADJACENT |
| | Shelter Service | A+E RECOMMENDS A 150KW GENERATOR WITH FANS AND FILTERS | | | |
| b. Other | Storage | MERCHANDISE + SUPPLIES | BAL. OF FL. | | PART OF SHELTER AREA |
| | | LOCKER RMS. + TOILETS | 7,600 S.F. | | PART OF SHELTER AREA |
| | Offices | NONE | | | |
| | | CHECK ROOM | 1,500 S.F. | | PART OF SHELTER AREA |
| | Shelter Supply | 1124 CTNS. BISCUITS<br>820 WATER DRUMS<br>91 CTNS. LINERS<br>182 SANITATION KITS IV<br>28 MEDICAL KITS C<br>1 RADEF KIT-777-1 | 900 S.F. | | IN AND ADJACENT TO SHELTER AREA |

c. Remarks:

WATER DRUMS STACKED 4 AND 5 HIGH - NOT FILLED

# SHELTER FIRE PROTECTION SURVEY FORM B

Building Name and Address: ANYTOWN DEPARTMENT STORE
City and State: ANYTOWN ALLSTATE

Date: JAN. 1, 1963
Surveyor: J. DOE

FLOOR ON WHICH SHELTER AREA LOCATED--STRUCTURAL
(Use one sheet for each floor having a shelter area)

Floor: THIRD

IV. PHYSICAL DESCRIPTION

a. Floor area: 41,400 b. Shelter capacity: 1590 c. Shelter area: 15,900 d. Ceiling height: 12'

e. Material used for finish of interior:
PLASTER WALLS AND CEILING; LINOLEUM FLOOR.

f. Structural separation of shelter area:
4" CONCRETE FLOOR AND CEILING; 12" CONCRETE EXTERIOR WALLS.

g. Protection of floor openings (other than to shelter area if area separated structurally):

V. OPENINGS INTO SHELTER AREA (Include floor opening protection when shelter not separated):

a. Door openings

| | Purpose | Width | Height | Direction (in/out) | Door Const. | U. L. Class | Single / Dbl. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1. | STAIRS 1, 2, 3, 1E-D1 | 3' | 7' | OUT | METAL | -- | SINGLE | 1-3/4" METAL, PANEL |
| 2. | PASS ELEVATORS D2 | 5' | 7' | SLIDING | METAL | -- | SINGLE | 1-1/2" METAL, FLUSH, HOLLOW CORE |
| 3. | FRT. ELEVATOR D-3 | 8' | 7' | UP/DOWN | METAL | -- | SINGLE | 1-3/4" METAL, PANEL |
| 4. | FRT. ELEVATOR D-4 | 6' | 7' | UP/DOWN | METAL | -- | SINGLE | 1-3/4" METAL, PANEL |
| 5. | PAPER CHUTE D-5 | 2' | 3' | UP | METAL | -- | SINGLE | 1-1/2" METAL, PANEL |
| 6. | SPIRAL CHUTE D-6 | 3' | 3' | OUT | METAL | -- | SINGLE | 1-1/2" METAL, PANEL |
| 7. | DUMB WAITER D-7 | 2'6" | 3' | UP/DOWN | METAL | -- | SINGLE | 1-1/2" METAL, PANEL |

b. Other openings (Access panels, holes, pipes, chases, ducts, drains, etc.) Describe:
ESCALATORS, 1ST. TO 5th FLOOR - OPEN AT ALL LEVELS
AIR DUCTS HAVE FIRE DAMPERS

c. Remarks:

VI FIRE PROTECTION EQUIPMENT--Describe and locate:

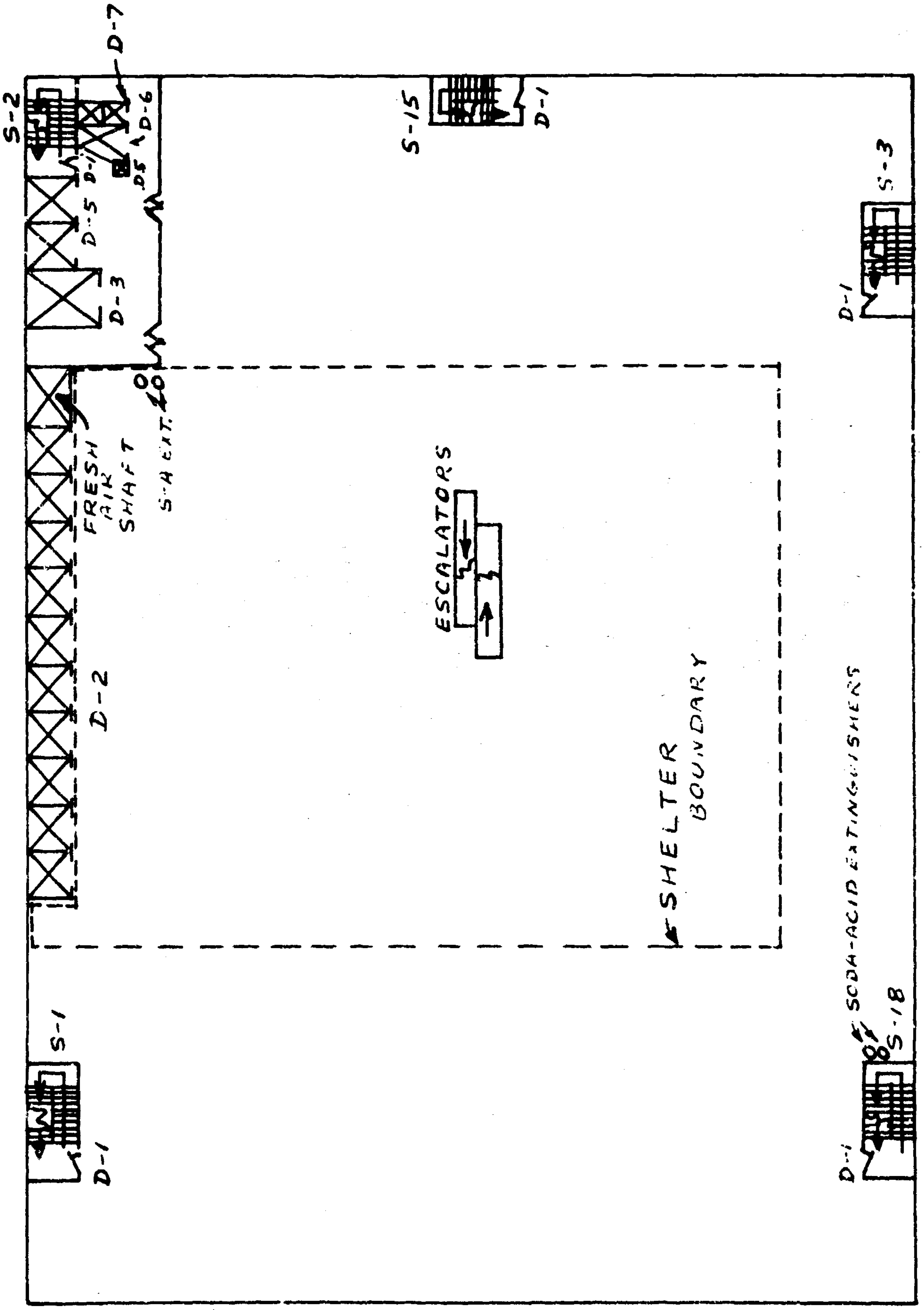
a. Portable extinguishers: SODA-ACID AS INDICATED

b. Small hose on standpipe: NONE

c. Fixed extinguishing systems: ENTIRE AREA COVERED BY AUTOMATIC SPRINKLERS

d. Remarks:

VII. PLAN VIEW OF FLOOR (Show on reverse side; scale not smaller than 1 inch = 50 feet.)




TYPICAL UPPER FLOOR

SCALE 1" = 30'

## SHELTER FIRE PROTECTION SURVEY FORM C

Sheet 13 of 21

Building Name and Address: ANYTOWN DEPARTMENT STORE Date: JAN. 1, 1963
City and State: ANYTOWN, ALLSTATE Surveyor: J. DOE

FLOOR ON WHICH SHELTER AREA LOCATED -- CONTENTS
(Use one sheet for each floor having a shelter area)

Floor: THIRD

| VIII. OCCUPANCY | | Description | Floor area Size or % of total | Occu. Density (sparse, avg., congested) | Location with respect to and separation from shelter area (See IVf and V on Form B) |
|---|---|---|---|---|---|
| a. Equipment and Utilities | Mfg. or Process | NONE | | | |
| | Bldg. Service | NONE | | | |
| | Shelter Service | NONE | | | |
| b. Other | Storage | SALES AREA | ENTIRE FLR. | AVERAGE | CONTAINS SHELTER AREA |
| | Offices | NONE | | | |
| | Shelter Supply | NONE | | | |

c. Remarks:

SHELTER FIRE PROTECTION SURVEY FORM D

Sheet 14 of 21

Building Name and Address: ANYTOWN DEPARTMENT STORE
City and State: ANYTOWN, ALL STATE

Date: JAN. 1, 1963
Surveyor: J. DOE

ENVIRONMENTAL DATA

IX. BUILDINGS AND STRUCTURES

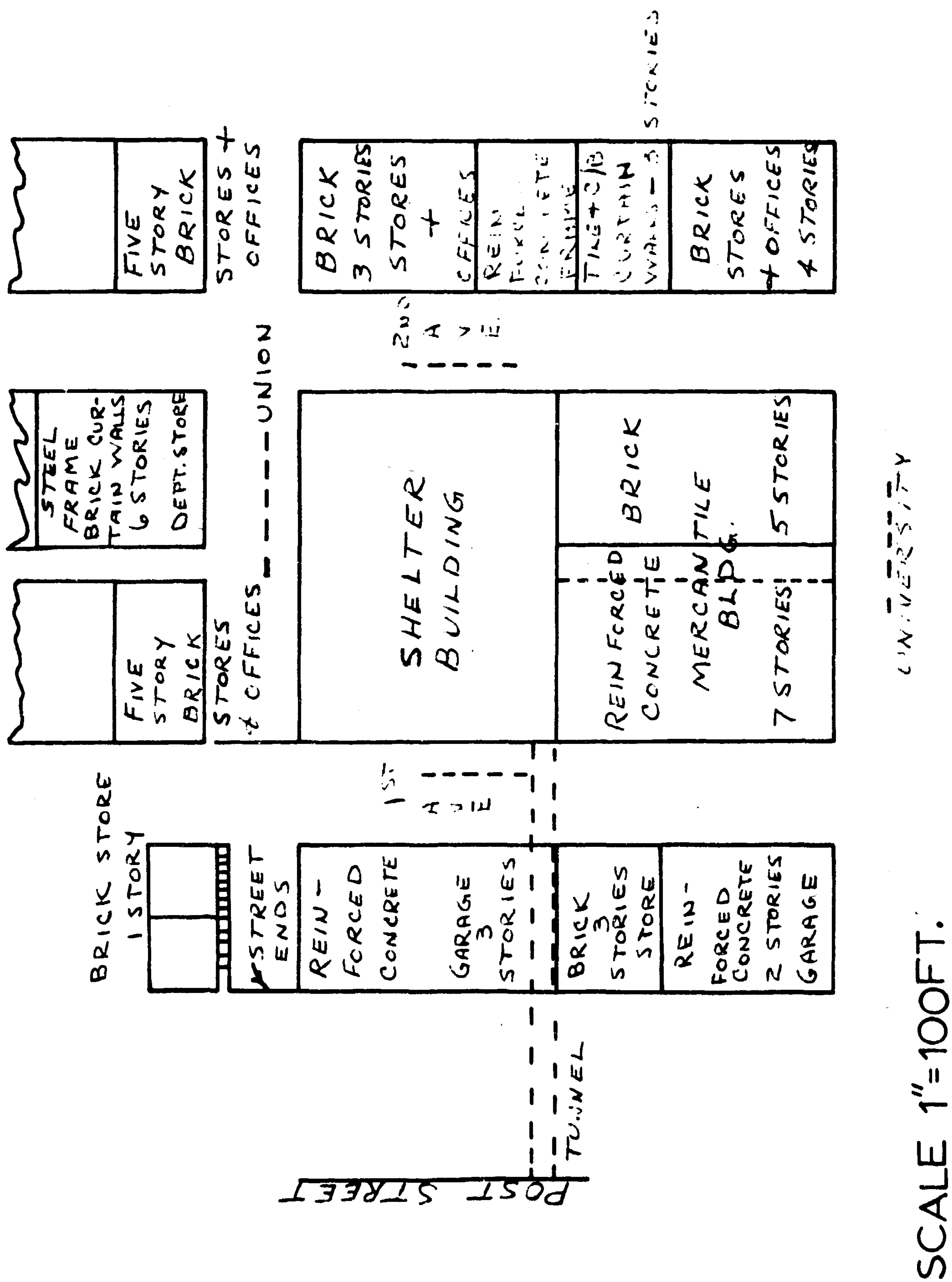
| | Address | Dist. (ft.) | Construction | Ground flr. area | Height no. flrs. | % Windows Facing Street flr. | % Windows Facing Typcl. flr. | Occupancy |
|---|---|---|---|---|---|---|---|---|
| North | 100 UNION | 66 | BRICK | 6,300 | 5 | 50 | 35 | STORES, 1ST; OFFIC. ABOVE |
| | 122 UNION | 66 | STEEL FRAME, BRICK WALLS | 12,075 | 6 | 50 | 40 | DEPARTMENT STORE |
| South | 1313 - 2ND AVE. | 0 | REINFORCED CONCRETE + BRICK | 43,700 | 7+5 | 0 | 0 | DEPARTMENT STORE |
| East | 1320 - 2ND AVE. | 66 | REINFORCED CON., TILE + C.B. WALLS | 7,000 | 3 | 60 | 60 | STORES + OFFICES |
| | 1326 - 2ND AVE. | 66 | BRICK | 12,000 | 3 | 35 | 25 | STORES + OFFICES |
| West | 1321 - 1ST AVE. | 66 | REINFORCED CONCRETE | 18,000 | 3 | 55 | 20 | GARAGE |

X. LAND FEATURES (General topography, features affecting fire fighting or influencing wind characteristics, tracks, tunnels, bridges, etc.): LAND RISES TO NORTH AND EAST. DROPS OFF SHARPLY TO THE WES[T] UNION STREET DEAD-ENDS TO THE WEST AT 1ST AVE. HOMER BAY, 3 BLKS. TO THE WEST.

XI. UNUSUAL UTILITY SITUATIONS (Significant locations of gas mains, transformers, power lines, sanitary and storm sewers, water mains, etc.):

NOTHING UNUSUAL

XII. PLAN OF RELATIVE POSITION OF ABOVE (Use reverse side; 1 inch = 50 feet or 100 feet.)


FIVE STORY BRICK
STORES + OFFICES
STEEL FRAME BRICK CUR-TAIN WALLS 6 STORIES DEPT. STORE
UNION
FIVE STORY BRICK
STORES + OFFICES
BRICK 3 STORIES STORES + OFFICES
2ND AVE
SHELTER BUILDING
BRICK 5 STORIES
REIN FORCED CONCRETE MERCANTILE BLDG. 7 STORIES
BRICK STORES + OFFICES 4 STORIES
UNIVERSITY
BRICK STORE 1 STORY
STREET ENDS
1ST AVE
REIN-FORCED CONCRETE GARAGE 3 STORIES
BRICK 3 STORIES STORE
REIN-FORCED CONCRETE 2 STORIES GARAGE
TUNNEL
POST STREET
SCALE 1"=100FT.

## APPENDIX B

## DATA SUMMARY AND CALCULATIONS FOR SAMPLE SURVEY

The following pages present the data summary and calculations performed on the building described in Appendix A. Pages B-2 and B-3 are concerned with the basement. Pages B-4 and B-5 are typical of any floor from the second through the seventh. The following symbols appear on the forms:

- $A_s$ = exposed area of combustible surfaces, $ft^2$
- $A_f$ = floor area, $ft^2$
- $S_r$ = $A_s/A_f$
- $A_w$ = area of openings supplying ventilation, $ft^2$
- $H$ = height of openings supplying ventilation, ft
- $L_w$ = sum of widths of openings supplying ventilation, ft
- $L_c$ = length of perimeter cracks around doors, etc., ft
- $R_s$ = burning rate based on fuel surface area, lb/min
- $R_v$ = burning rate based on ventilation, lb/min
- $R_{rv}$ = burning rate for very restricted ventilation, lb/min

DATA SUMMARY

Floor: BASEMENT

Building: ANYTOWN DEPARTMENT STORE

## GENERAL INFORMATION

General Class: DEPARTMENT STORE

Sub-Usages: STORAGE, LOCKERS, WRAPPING, FAN ROOM, CARPENTER SHOP

Total Floor Area $(ft)^2$ 36,720

Avg. Ratio Combustible Surface to Floor Area $(lb/ft^2)$ 4

Avg. Weight Combustibles per Floor Area(lb) 15

Window Height(ft) NONE Outside Floor Height(ft) NONE

Percentage Outside Window Openings:

Front 0 Rear 0 Right 0 Left 0

Portable Extinguishers 4 SODA-ACID, 2 DRY-CHEM.

Fire Hose Coverage NONE

Automatic Sprinkler Coverage 100%

Fire Protection Water Supply CITY

## SUBDIVISION RATINGS

| | Size (ft) | Material | No. Openings: Corridor /Shafts | No. Openings: Direct | Least Fire Rating (min) |
|---|---|---|---|---|---|
| Avg. Partition Area | 90 x 40 | CONCRETE | — | — | 116 |
| Partition Doors | 3 x 7 | METAL | 0 | 11 | 56 |
| Floor Construction | 171 x 237 | CONCRETE | — | — | 116 |
| Staircase/CHUTES | 3 x 7 / 2.5 x 3 | METAL/METAL | 2 / 3 | 5 / 0 | 56/56 |
| Elevator, PASS/FREIGHT | 5 x 7 / 8 x 7 | METAL/METAL | 3 / 4 | 0 / 0 | 56/56 |
| Other Floor Openings (AIR DUCTS) | UNK. | METAL DAMPERS | — | ALL | 56 |

IIT RESEARCH INSTITUTE

COMPUTATION SHEET

Floor: BASEMENT

Building: ANYTOWN DEPARTMENT STORE

PREDICTED FLASHOVER SEQUENCE

| Time (min) | Flash-over | Size (ft) | Area ($ft^2$) | $R_s$ * (lbs/min) | $L_w$ (ft) | $H^{3/2}$ | $R_v$ ** (lbs/min) |
|---|---|---|---|---|---|---|---|
| N.A. | 1st | 10 x 12 | 120 | 43.2 | $L_c$ = 20 | | $R_{nv}$*** = 2.1 |
| | 2nd | 20 x 24 | 480 | 172.8 | | | |
| | 3rd | 40 x 48 | 1920 | 691.2 | | | |
| | 4th | 80 x 90 | 7200 | 2600 | | | |
| | 5th | | | | | | |
| | 6th | | | | | | |

$*R_s = 0.09\ A_s = 0.09\ S_r A_f$ $**R_v = 0.678\ A_w H^{1/2} = 0.678\ L_w H^{3/2}$

$***R_{nv} \simeq 0.0103\ L_c$

PEAK FIRE DURATION

$$\text{Peak Fire Duration} = \frac{0.5\ (\text{Area})(\text{Combustibles/Area})}{(\text{Minimum Burning Rate})}$$

Avg. Partitioned Area: $\frac{(0.5)(7200\ ft^2)(15\ lbs/ft^2)}{(\quad lbs/min)}$ = 26,200 min

Entire Floor Area: $\frac{(0.5)(\quad ft^2)(\quad lbs/ft^2)}{(\quad lbs/min)}$ = — min

RESISTANCE OF FIRE BARRIER (N.A.)

Resistance = Rating + Additional Build-up + Secondary Barriers

Avg. Partitioned Area: ____(R) + ____(BU) + ____(SB) = — min

Entire Floor Area: ____(R) + ____(BU) + ____(SB) = — min

SPREAD POTENTIAL (N.A.)

Spread Potential = Peak Fire Duration - Resistance(based on last flashover)

Average Partitioned Area: ____(PFD) - ____(Res) = — min

Entire Floor Area: ____(PFD) - ____(Res) = — min

## DATA SUMMARY

Floor: SECOND THROUGH SEVENTH

Building: ANYTOWN DEPARTMENT STORE

### GENERAL INFORMATION

General Class: DEPARTMENT STORE

Sub-Usages: SALES AREA

Total Floor Area(ft)$^2$ 42,500

Avg. Ratio Combustible Surface to Floor Area(lb/ft$^2$) 4

Avg. Weight Combustibles per Floor Area(lb) 15

Window Height(ft) 7 Outside Floor Height(ft) 12

Percentage Outside Window Openings:

Front 30 Rear 0 Right 30 Left 30

Portable Extinguishers 4 SODA-ACID

Fire Hose Coverage NONE

Automatic Sprinkler Coverage 100%

Fire Protection Water Supply CITY

### SUBDIVISION RATINGS

| | Size (ft) | Material | No. Openings: Corridor /Shafts | No. Openings: Direct | Least Fire Rating (min) |
|---|---|---|---|---|---|
| Avg. Partition Area | 150×220 | CONCRETE | — | — | 116 |
| Partition Doors | — | NONE | — | — | — |
| Floor Construction | 174-252 | CONCRETE | — | - | |
| Staircase | 3×7 | METAL | 5 | 1 | 56 |
| ESCALATOR | 6×20 | OPEN | 0 | 1 | 5 |
| Elevator, PASS/FREIGHT | 5×7/8×7 | METAL/METAL | 10/3 | 0/0 | 56/56 |
| Other Floor Openings (CHUTE) | 2.5×3 | METAL | 1 | 0 | 56 |

## COMPUTATION SHEET

Floor: SECOND THROUGH SEVENTH

Building: ANYTOWN DEPARTMENT STORE

### PREDICTED FLASHOVER SEQUENCE

| Time (min) | Flash-over | Size (ft) | Area ($ft^2$) | $R_s$* (lbs/min) | $L_w$ (ft) | $H^{3/2}$ | $R_v$** (lbs/min) |
|---|---|---|---|---|---|---|---|
| 20 | 1st | 10 × 12 | 120 | 43.2 | 6.6 | 18.5 | 83 |
| 10 | 2nd | 20 × 24 | 480 | 172.8 | 13.2 | 18.5 | 166 |
| 10 | 3rd | 40 × 48 | 1920 | 691.2 | 26.4 | 18.5 | 332 |
| 10 | 4th | 80 × 96 | 7680 | 2765 | 52.8 | 18.5 | 664 |
| 10 | 5th | 150 × 220 | 33,000 | 11,880 | 157 | 18.5 | 1510 |
| | 6th | | | | | | |

$*R_s = 0.09\ A_s = 0.09\ S_r A_f$ $\quad **R_v = 0.678\ A_w H^{1/2} = 0.678\ L_w H^{3/2}$

### PEAK FIRE DURATION

$$\text{Peak Fire Duration} = \frac{0.5\ (\text{Area})(\text{Combustibles/Area})}{(\text{Minimum Burning Rate})}$$

Avg. Partitioned Area: $\frac{(0.5)(\quad ft^2)(\quad lbs/ft^2)}{(\quad lbs/min)}$ = — min

Entire Floor Area: $\frac{(0.5)(33{,}000\ ft^2)(15\ lbs/ft^2)}{(1510\ lbs/min)}$ = 164 min

### RESISTANCE OF FIRE BARRIER

Resistance = Rating + Additional Build-up + Secondary Barriers

Avg. Partitioned Area: ____(R) + ____(BU) + ____(SB) = — min

Entire Floor Area: 5 (R) + 10 (BU) + 0 (SB) = 15 min

### SPREAD POTENTIAL

Spread Potential = Peak Fire Duration - Resistance(based on last flashover)

Average Partitioned Area: ____(PFD) - ____(Res) = — min

Entire Floor Area: 164 (PFD) - 15 (Res) = 149 min

## APPENDIX C
## METHOD FOR ASSESSING FIRE VULNERABILITY

1. General

This system was developed to aid judgments of fire vulnerability in the selection of fallout shelter buildings. Specifically it indicates whether these buildings are "fire limiting," i.e., whether fire will spread beyond the floor where ignition takes place. This assessment is based on interior fire spread potential calculated by analytical means for 102 structures. It was developed by a trial and error method to give the same fire spread results as those calculated and treats the same three general areas employed in the analytical treatment: a) the fuel available in terms of fire load, b) the resistance afforded by the structure through subdivision, and c) the oxygen supply in terms of the window area.

With this system a total of 22 points may be charged against a building. When the total does not exceed 10, the property can be considered "fire limiting." When the total reaches 11 or more, the building should be considered either "suppression dependent" or "completely untenable." This system may be used for entire buildings using significant values or it may be used to draw conclusions about individual full floors. Reference should be made to Chapter V "Operational Guidance" for meanings of these groupings and full basis for judging shelter building suitability.

2. Combustible Fire Load

The total amount of combustible materials present in a building is one of the factors which determine the duration of a fire, and therefore the fire exposure that the building and its component parts are called upon to withstand. Known as the "fire load", this consists of contents items, building trim and floor surfacing in structures not having combustible structural members. A survey which reports representative values, "Combustible Contents in Buildings," U. S. Department of Commerce Building Materials and Structures Report 149, can be used as a basis for such calculations.

In making the assessment, the charge should be made against the floor having the highest average fire load:

| Load (lbs/sq.ft) | Points |
|---|---|
| Not greater than 3 | 0 |
| Greater than 3, but not greater than 8 | 4 |
| Greater than 8, but not greater than 15 | 6 |
| Greater than 15, but not greater than 25 | 8 |
| Greater than 25 | 10 |

3. Building Ventilation

The second factor relating to fire duration is the rate at which the available combustibles are burned. The burning rate is determined by the ventilation available to the fire. This ventilation is approximated by the proportion of window area to total wall area on every above-ground floor. Wired glass windows in metal frames and fully enclosed display windows should be disregarded.

If the effective window area percentage is less than 15 per cent but exceeds 6 per cent charge 2 points. If it does not exceed 6 per cent, charge 4 points.

4. Subdivision of Floor Areas

Where principal subdivided areas of the floors being considered exceed 25 per cent, the value of subdividing partitions and corridors should be considered in the following manner:

a. If corridors are wider than six feet or if all corridor openings are protected with metal doors not having louvers or ordinary glass sections, make no charge.

b. If corridors are six feet or narrower, but have a door of any description in all corridor openings, charge 2 points.

c. If no corridors or partitions exist with protected openings, charge 4 points.

5. Subdivision between Floors

a. If each floor opening is surrounded by a masonry shaft, with openings protected on each floor with metal doors not having louvers or ordinary glass section, make no charge.

b. If all floor openings are protected as specified above, but some protected openings are direct rather than through an intermediate shaft, charge 1 point.

c. If floor openings are protected but combustible doors, shafts or door linings are employed, charge 2 points.

d. If all floor openings are surrounded by shafts, but unprotected openings into a shaft exist, charge 3 points.

e. No floor opening protection, charge 4 points.

This system was developed for use in the selection of buildings on the basis of fire safety to confined fallout shelter occupants. It is limited to nonoperational, undamaged structures. The use of this evaluation means beyond this scope is not intended.